HEWLETT-PACKARD COMPANY IV

Component Layout of an Electronic Signal Analyzer

Mr. Charles Cook, a product designer in the microwave development laboratory at Hewlett-Packard Company recently received the assignment of laying out the interior of an electronic instrument which is now in the prototype stage of development. Electrical assemblies for some functions have not yet been completely designed although the instrument has been in development for about three months. While Mr. Cook is working on the interior mechanical layout, electrical engineers are proceeding with the selection and design of the prototype electrical sub-assemblies. Mr. Cook has been told by the project leader to treat the presently incomplete electrical sub-assemblies as "black boxes" of electronic equipment which must be arranged in locations most suited to their functions.

Hewlett-Packard

Founded in 1939, Hewlett-Packard has grown from a two-man company to an organization regarded as the world's largest producer of electronic test equipment. They manufacture a complete line of electronic and microwave test instrumentation, including oscilloscopes, audio oscillators, voltmeters, noise and distortion analyzers, signal generators, power meters, electronic counters, and a complete array of waveguide equipment. The company now employs over 6,000 people and has an annual sales volume of over $100 million. Although the main office is located in Palo Alto, California, manufacturing plants are also located throughout the United States, in England, Germany, and Japan. The company maintains sales and service offices in nearly every major city of the free world.

Signal Analyzer

The instrument which Mr. Cook was recently assigned to work on is a device for analyzing components of an electrical signal.

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by Eugene Echterling under the direction of Professor Peter Z. Bulkeley as a basis for student exercises with support of the National Science Foundation. The cooperation of Mr. Charles Cook and Mr. Donald Borthwick of the Hewlett-Packard Company is gratefully acknowledged.

A series of sinusoidal electrical signals can be superposed to form a complex signal which, when viewed on an oscilloscope, would give no visual indication of the strength or frequency of its various components. (Illustration A).

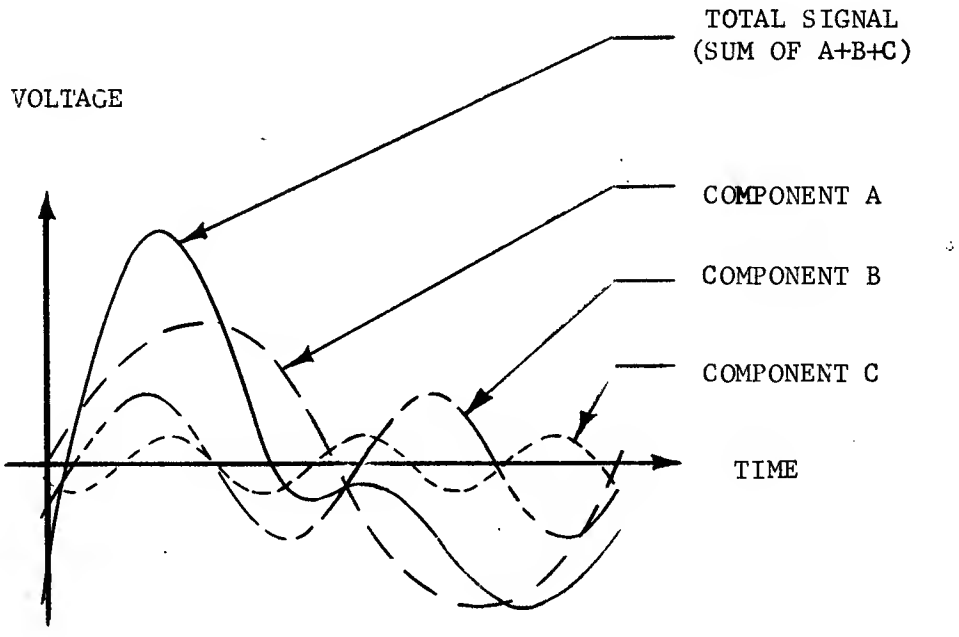

Illustration A

It is often necessary, however, to know how much of a certain frequency component is present in an unknown, complex signal. An example of such an instance might occur in the study of marine life: if it is known that a certain type of sea animal produces a sound at a frequency of 60,000 cycles per second (the limits of human audibility are approximately 20,200 cycles per second) and a microphone is used to convert ocean "noise" into an electrical signal, a signal analyzer could be used to filter out all components except the one at 60,000 cycles per second. The strength of such a component could be used to determine the approximate number of such sea animals in a given area.

The particular analyzer being developed is designed to isolate signals ranging from 20,000 to 100,000 cycles per second. Preliminary electrical models of the instrument have been tested, and prototype design of the overall instrument is now under way. The project is being carried out in the Microwave Products Laboratory where approximately 40 engineers are involved in the development of new instruments. The overall activities of the lab are the responsibility of the lab manager. Reporting directly to the

lab manager are several section managers. For each project being carried out, the section manager in charge assigns a project supervisor who coordinates the activities of the mechanical engineers, electrical engineers, and product designers working on the project.

Mr. Cook is the only product designer working on this project. His job is to design the interior of the cabinet which is to house the various electrical and mechanical components of the instrument. Although his educational background is in electrical engineering, he prefers working on design projects which involve mechanical as well as electrical considerations.

Modular Cabinet System

The external shapes of Hewlett-Packard instruments are designed to allow them to be grouped at the user's discretion (Exhibit 1). Several small instruments can be mounted in a cabinet identical in size to larger instruments housings or "modules". These assemblies can then be mounted in a rack with other full size modules. This cabinet system was introduced in 1961 to minimize the bulkiness of laboratory test systems which often combine many instruments in a single installation. With the former type of sheet metal wrap-around cabinets such as those housing early Hewlett-Packard instruments (Exhibit 2), test systems often take up more bench space. Only those instruments designed before 1961 still use the older wrap-around cabinets.

In selecting a module size for a new instrument, engineers at Hewlett-Packard consider power requirements, weight, panel area, and volume. The cabinets range in size from a 6" x 5-1/8" x 1-1/2" submodule with a 33 cubic inch volume to a 24-3/8" x 16-3/4" x 12-17/32" full module with a volume of 4061 cubic inches.

The new instrument that Mr. Cook is working on is to be housed in a 16-3/4" x 16" x 8-1/2" full width module (Exhibit 3). This decision was made by the project supervisor after reviewing the electrical schematic diagram and discussing component choices with electrical engineers on the project. Mr. Cook's job is to design interior decking for mounting the components in the instrument. (A typical H-P deck is shown in Exhibit 3-A)

Front Panel Components

The basic structure of the module chosen consists of two identical die-cast aluminum side frames (Exhibit 4), plus front and back panels (Exhibits 5 and 6). The front panel for this instrument is to be an optional model (Exhibits 7 and 7A) with a horizontal window 2-3/16" wide across the upper portion. The window opening is blanked from the front panel prior to bending. At installation the opening is covered across the full width with a 1/16" thick piece of clear plastic held in place by identical upper and lower extrusions. The clear plastic cover and the extrusions are inserted from the side of the panel and are held in place by the side frames of the instrument. There are several methods used to blacken the portion of the window

not in use. Sometimes a black painted aluminum panel is placed behind the window with mounting screws fastening it to the side frame of the instrument. Another method is to mask off the desired clear portion of the window and then spray the back of the window with black paint.

The detailed layout of the panel, including placement of controls and location of readout, is being designed by the industrial designer assigned to Microwave Products Division. Mr. Cook knows, however, that the panel layout will generally be much like that of other instruments in Hewlett-Packard's product line. (A previous front panel is shown in Exhibit 7B). The company typically places input functions on the left side of the panel and output functions on the right. The components to be located on the front panel are:

INPUT	OUTPUT
AC Power Switch (Ex.8)	Range Selector (Ex.11)[2]
AC Power Pilot Light (Ex.9)	Coarse Frequency Control (Ex.12)
Input Connector (Ex.10)	Fine Frequency Control (Ex.12)
Input Level Control (Ex.11)[1]	Recorder Output Connector (Ex.13)
	Output Coaxial Connector (Ex.13)
	Output Voltage Meter (Ex.14, 14A)
	Output Frequency Indicator (Ex.15)

The frequency selection controls are used to isolate for analysis any frequency component of the input signal between 20,000 and 100,000 cycles per second. The frequency to which the instrument is tuned can be read directly from a five place digital readout composed of five decade counters mounted behind the window across the front panel of the instrument. The counters (Exhibit 16) are produced by Hewlett-Packard's Frequency and Time Division and are used in many of their instruments. Each counter consists of a digital indicator tube (Exhibit 15) mounted on a molded plastic bracket with an attached printed circuit board containing an electronic logic circuit. The printed circuit board has a 15 pin connector tab which fits a standard chassis mounting 15 pin printed circuit board connector (Exhibit 17). Any number of these counters can be mounted side by side to give as many digits as are needed. The Frequency and Time Division is in the process of redesigning the front portion of the decade counters to facilitate their installation in groups where a 3, 4, 5, or more, digital readout is required. Mr. Cook explained how this affects him, "Since the mounting structure for the counters is being redesigned, I won't design one especially for this instrument. I have been told to mount only the 5 printed circuit board connectors for the counters so that the 5 digit readout is centered in the

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[1] Input Level Control - a rotary switch used to select any of nine voltages as the maximum total input (Exhibit 11A)

[2] Range Selector - an eight station rotary switch for selecting one of eight scales on the voltage meter.

right half of the panel window. I know, however, that they will be mounted directly side by side with the upper front portion approximately 1/8" behind the front panel of the instrument."

The strength of the signal component being analyzed can be read directly from the voltage meter mounted in the left half of the window on the front panel of the instrument. The voltage meter is mounted directly to the front panel, therefore no provision need be made for mounting the meter on any interior decking.

No exposed screw heads are desired on the front panel of the instrument. All decks within the instrument are to be attached to the side frames by means of screws through the existing die cast clearance holes for a number 8-32 screw or through the captive nuts which are pressed into the frames after casting.

Electronic Sub-assemblies

The project supervisor explained to Mr. Cook that some of the prototype electronic circuitry is still being designed. From analysis of the electrical schematic, however, the supervisor has decided what maximum volumes this circuitry will be allowed. He told Mr. Cook to regard three areas in the instrument as "black blxes" for the present time. The general function of each of the three electronic packets is known however. One contains circuitry directly related to the input signal; one is related to the output signal; one handles the signal between input and output stages (Electrical Block Diagram is shown in Exhibit 18). The minimum dimensions for each "black box" area are to be 4-3/8" x 5" x 7-1/2". Mr. Cook was told by electrical engineers on the project that electrical interference problems require that each area be completely surrounded by metal (decking or part of the cabinet) and isolated from the rest of the instrument. Mr. Cook explained how these three "black boxes" affect his thinking, "I know the general function of each of these volumes and I know they contain electrical circuitry. Also, I know the input and output functions must be connected with the input and output controls on the front panel of the instrument. This gives me enough information to locate them within the instrument."

Although the electrical engineers working on the circuitry of the "black boxes" are expected to fit all their components and sub-assemblies into their allotted volumes, they realize there is some flexibility. Mr. Cook explained what will happen if more room is needed. "The electrical engineers will discuss the problem with the project supervisor. He will try to keep the assemblies within the assigned 4-3/8" x 5" x 7-1/2" volume. If this cannot be done, the problem will be discussed with me and we will see what effect a change in dimensions of one of the "black boxes" will have on the rest of the interior layout. If the interior design is quite far along and a change would require considerable effort, the electrical engineer will be told he must fit his assembly in the given area. If this is impossible, some compromise will be reached, of course."

Power Supply

Mr. Cook explained considerations on the location of the power supply, "Customarily, this is located in the rear of the instrument. The power cord is normally at the rear, so the placing of the power supply there minimizes electrical interference resulting from electric fields induced by the alternating current of the power cord. Leads must run from the rear to the power switch on the front panel. Since these are 110 volt alternating current leads, they too can sometimes cause interference. When this occurs, they must be shielded by a metallic cover designed for this purpose. In this instrument, however, I have been told by the electrical engineers that alternating current interference will not be a problem." The power supply consists of:

1 transformer	4 rectifiers
5 capacitors	4 power transistors
2 printed circuit boards	

The transformer has been designed by Palo Alto Engineering Company (PAECO), a subsidiary of Hewlett-Packard. The overall dimensions of the transformer are given in Exhibit 19.

Two sizes of capacitors are used in the power supply. Both are housed in standard capacitor housing cans. There are three large capacitors, 3-1/4" high x 1-3/8" diameter, and two smaller ones, 2-3/4" high x 1" diameter. All capacitors must be insulated from the chassis. Mounting holes and insulating wafer sizes are shown in Exhibit 20.

The printed circuit boards associated with the power supply are the size shown in Exhibit 21 The minimum clearance for electronic components mounted on the boards is 7/8" (components mounted on one side only). Boards are mounted where they can readily be inserted and removed with minimum disassembly of the instrument. This facilitates assembly and permits easy removal of electronic circuits for testing and replacement. In one system of mounting printed circuit boards, decks are designed with punched "lances" which act as guides and supports for the boards which can be slid into place with their tabs slipped into standard 15-pin connectors (Exhibit 22).

The four rectifiers (Exhibit 23) must be gounded to the chassis.

The four power transistors (Exhibit 24) must be insulated from the chassis. In addition, they must dissipate the heat (10 watts per transistor) they generate during operation. Mr. Cook commented on this problem, "If I can mount these so the heat will be conducted to the side frame of the instrument, the heat will then mostly be dissipated to the air outside the instrument. In some instruments, cooling fans are required to aid in dissipating large amounts of heat from within the instrument. In this instrument, however, electrical engineers have determined from power considerations that no cooling fan will be needed."

Additional Printed Circuit Boards

There are 3 additional groups of printed circuit boards to be located in the instrument. These are:

Detector group
Filter group
Counter group

All of these boards are the size shown in Exhibit 21. Maximum height of electronic components (one side only) is 7/8". All have 15-pin tabs which fit the connector shown in Exhibit 17.

The detector group consists of 4 boards. Their function relates to the "black box" associated with the input signal. The filter group consists 6 boards, all related to the "black box" which handles the input signal between input and output stages. The counter group consists of 2 boards whose function is related to the group of 5 decade counters providing frequency readout on the panels.

Decking and Wiring

Mr. Cook explained his concern for wiring among the internal sub-assemblies, "I must keep in mind the relationship between various sub-assemblies and their location, but it is not necessary for me to design the wiring diagram for the completed instrument. This will be done by electrical engineers following my design of the interior component layout. Some changes may be necessary as a result of wiring interference, but this is the purpose of the prototype stage; the bugs must be worked out. In making the wiring diagram, the electrical engineers will decide where holes must be punched in the interior decking to accommodate the necessary bundles of wires." Sheet metal forming and punching practices are discussed in Exhibit 25.

Summary

Mr. Cook is not doing the layout of the front panel. His job is to lay out, in a functional manner within the instrument, the following components:

ITEM	QUANTITY
Decade Counter	5
"Black Box" (4-3/8" x 5" x 7-1/2" min.)	3
Power Supply	
Transformer	1
Capacitor	5
P.C. Board	2
Rectifier	4
Power Transistor	4
Detector P.C. Board	4
Filter P.C. Board	6
Counter P.C. Board	2
(Meter mounts on front panel)	

Decks must be designed for mounting all of the above components. In addition, the decks are to serve as structural members, giving the instrument added rigidity. Since the finished prototype will be subjected to drop tests and vibrational tests, all components must be capable of withstanding shock in all directions.

Keeping the number of decks to a minimum is desirable. However, no loss of function should occur as a result of combining interior structure.

Exhibit 1: Arrangement of various instruments showing different module sizes.

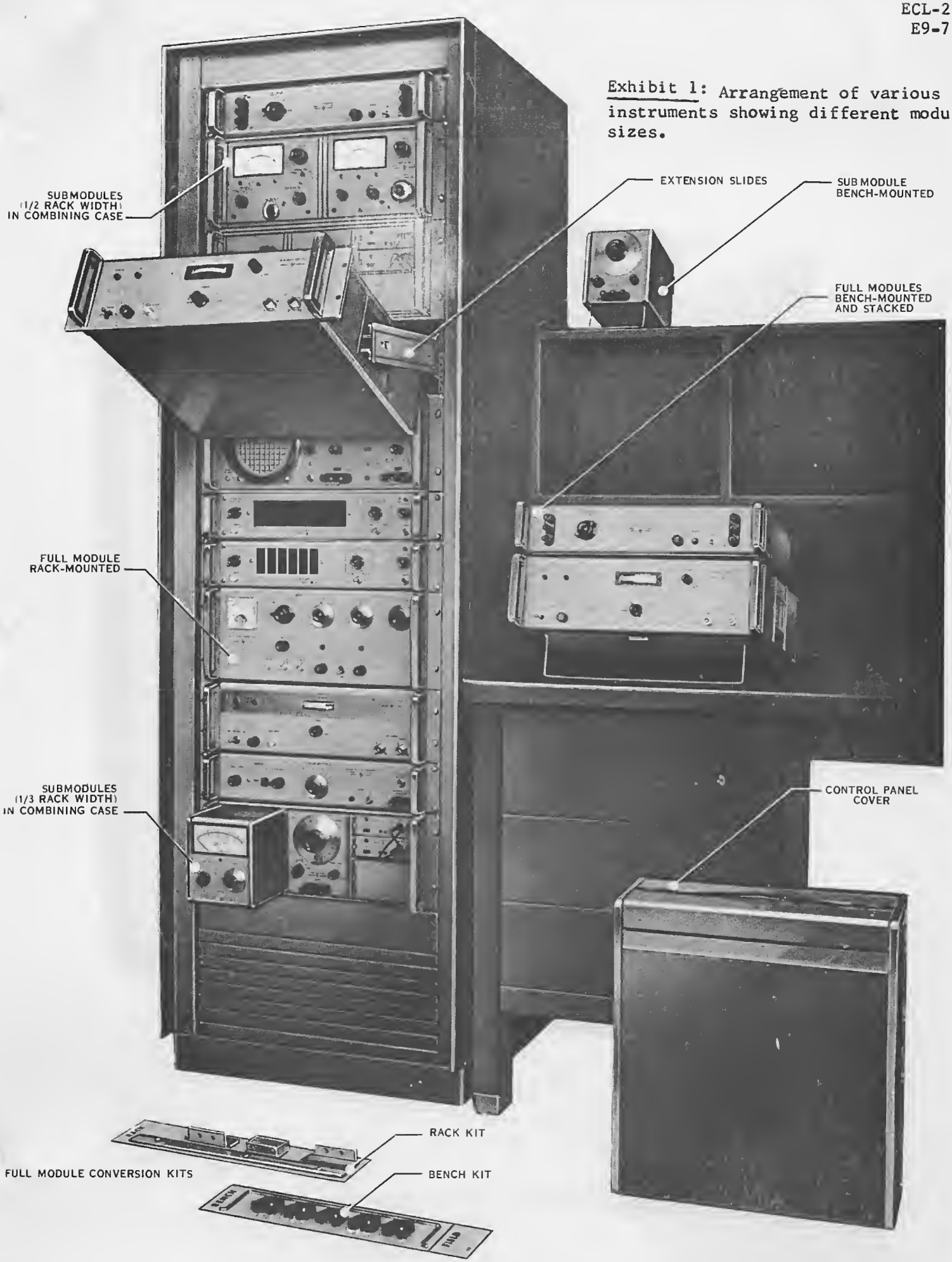
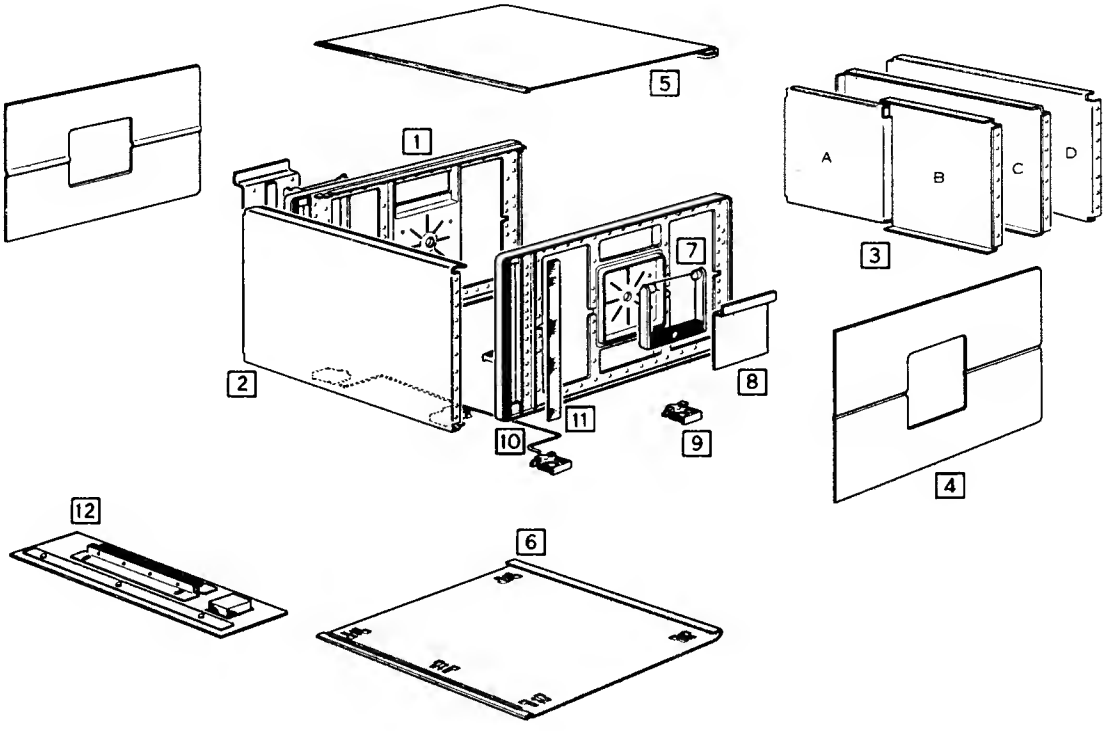


Exhibit 2: Older style instrument housing.

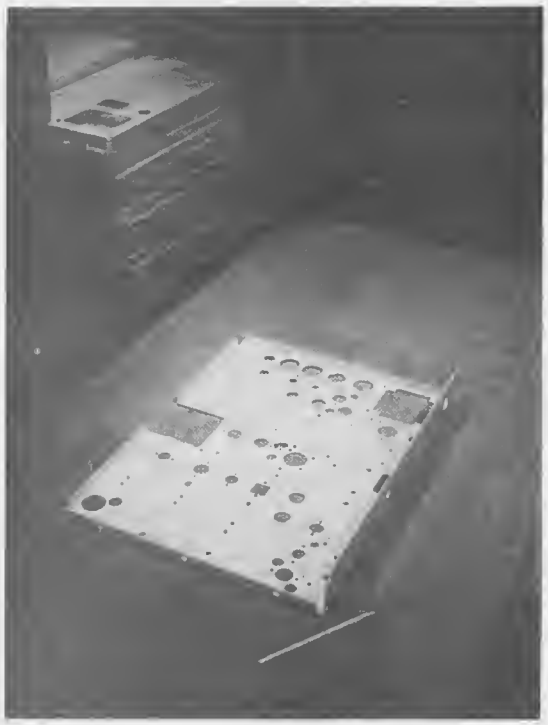
MODULAR CABINET SYSTEM

8x16 FULL MODULE SIZE 11



DESCRIPTION	QTY.	PART NO.	DWG NO.
1. FRAME ASS'Y - 8 x 16 FM	2	5060-0736	D-5060-0736-2
** 2. FRONT PANEL - 8H FM	1	* 5000-0769	D-5000-0769-1
3. REAR PANEL - 8H FM	1		
§ A. Half Recess		* 5000-0771	C-5950-0723-1
§ B. Half Non Recess		* 5000-0772	C-5950-0727-1
C. Non Recess		* 5000-0773	D-5950-0729-1
D. Full Recess		* 5000-0770	D-5950-0720-1
4. SIDE COVER - 8 x 16 FM	2		
A. Non Perforated		5000-0746	C-5000-0746-1
B. Perforated		5000-0747	C-5000-0747-1
5. TOP COVER ASS'Y - 16L FM	1		
A. Non Perforated		5060-0740	D-5950-0732-1
B. Rear Perforated		5060-0743	D-5950-0734-1
C. Front Perforated		5060-0746	D-5950-0736-1
D. Full Perforated		5060-0749	D-5950-0738-1
6. BOT. COVER ASS'Y - 16L FM	1		
A. Non Perforated		5060-0752	D-5950-0739-1
B. Rear Perforated		5060-0755	D-5950-0741-1
C. Front Perforated		5060-0758	D-5950-0743-1
D. Full Perforated		5060-0761	D-5950-0745-1
7. HANDLE ASS'Y - SIDE	2	5060-0763	A-5060-0763-2
8. RETAINER - HANDLE ASS'Y	2	5060-0765	B-5060-0765-1
9. FOOT ASS'Y - FM	5	5060-0767	A-5060-0767-1
10. STAND - TILT	1	1490-0030	50M-M-2743
11. PLATE - FLUTED AL.	2	5000-0053	A-5950-0009-1
12. KIT - 8H RACK MOUNT	1	5060-0777	NONE

* NOT FOLDED ** SEE FM OPTIONS § USED TOGETHER



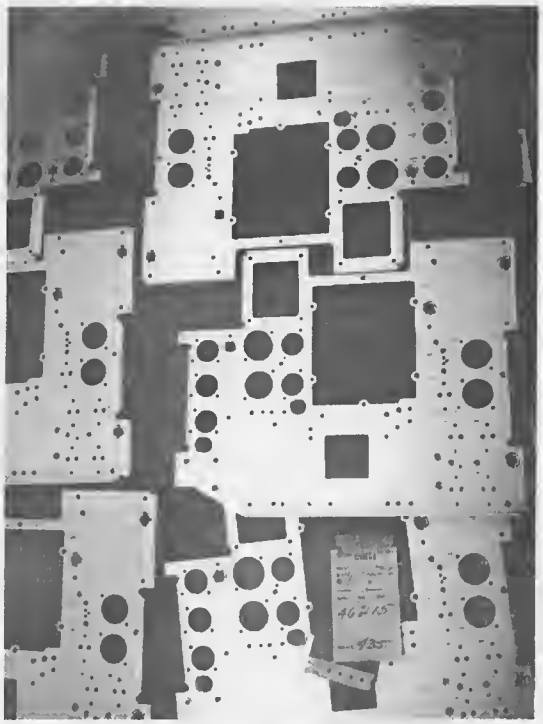


Exhibit 3-a: Typical Decking.

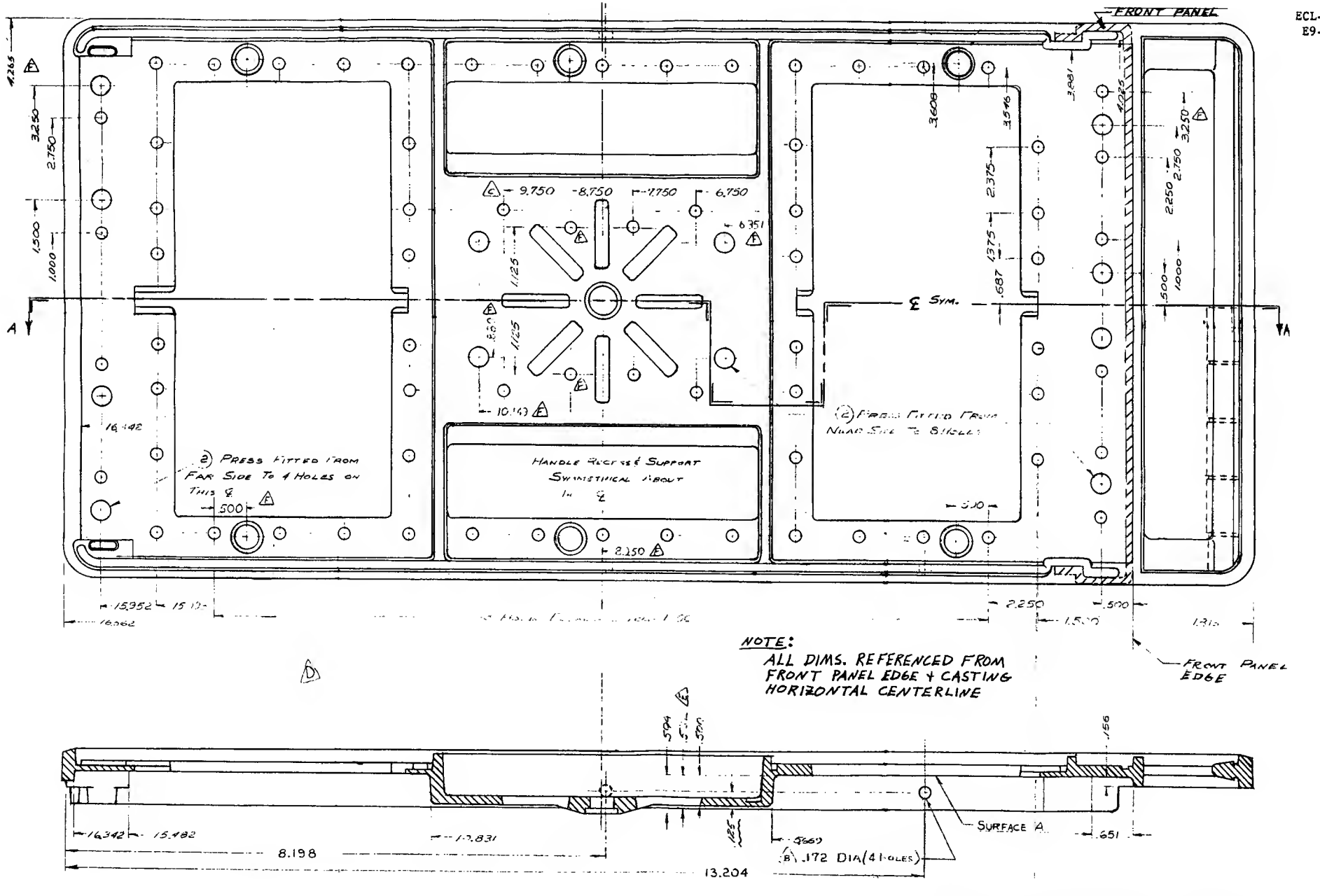


Exhibit 4: Side Frame Drawing. (Three-Quarter Scale)

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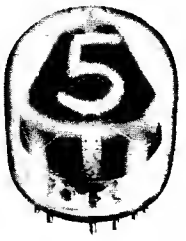
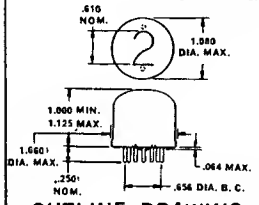


STANDARD

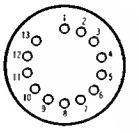
STANDARD
RECTANGULAR

CHARACTER SIZE .6″

VIEWING DISTANCE 30′

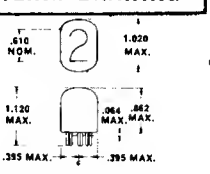


OUTLINE DRAWING

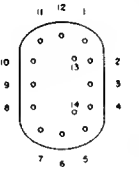


PIN CONNECTIONS

PIN NO.	CHARACTER
1	Internal Connection
2	Anode
3	Numeral 0
4	Numeral 9
5	Numeral 8
6	Numeral 7
7	Numeral 6
8	Internal Connection
9	Numeral 5
10	Numeral 4
11	Numeral 3
12	Numeral 2
13	Numeral 1



OUTLINE DRAWING



PIN CONNECTIONS

PIN NO.	CHARACTER
1	Anode
2	Numeral 0
3	Numeral 9
4	Numeral 8
5	Numeral 7
6	Numeral 6
7	Numeral 5
8	Numeral 4
9	Numeral 3
10	Numeral 2
11	Numeral 1
12	Internal Connection
13	Internal Connection
14	Internal Connection

ELECTRICAL DATA

	B5991 Ultra Long Life Rectan-gular	6844A Regular	8037 (B5031) Long Life	B5092 Long Life Wide Angle
Absolute Ratings Ionization Voltage (Max)	170 Vdc	170 Vdc	170 Vdc	170 Vdc
Supply Voltage (Min)	170 Vdc	170 Vdc	170 Vdc	170 Vdc
Cathode Current (Peak)	3.5 ma	4.0 ma	3.5 ma	3.5 ma
Test Conditions				
Supply Voltage	170 Vdc	170 Vdc	170 Vdc	170 Vdc
Series Resistor	8.2K	15K	10K	10K
Cathode Current: (Min) (Max)	1.5 ma 3.0 ma	1.5 ma 3.0 ma	1.5 ma 3.0 ma	1.5 ma 3.0 ma

Exhibit 15: Indicator Tube.

*NOTE:
Standard Round Indicator Tube
is Used in Exhibit 16.

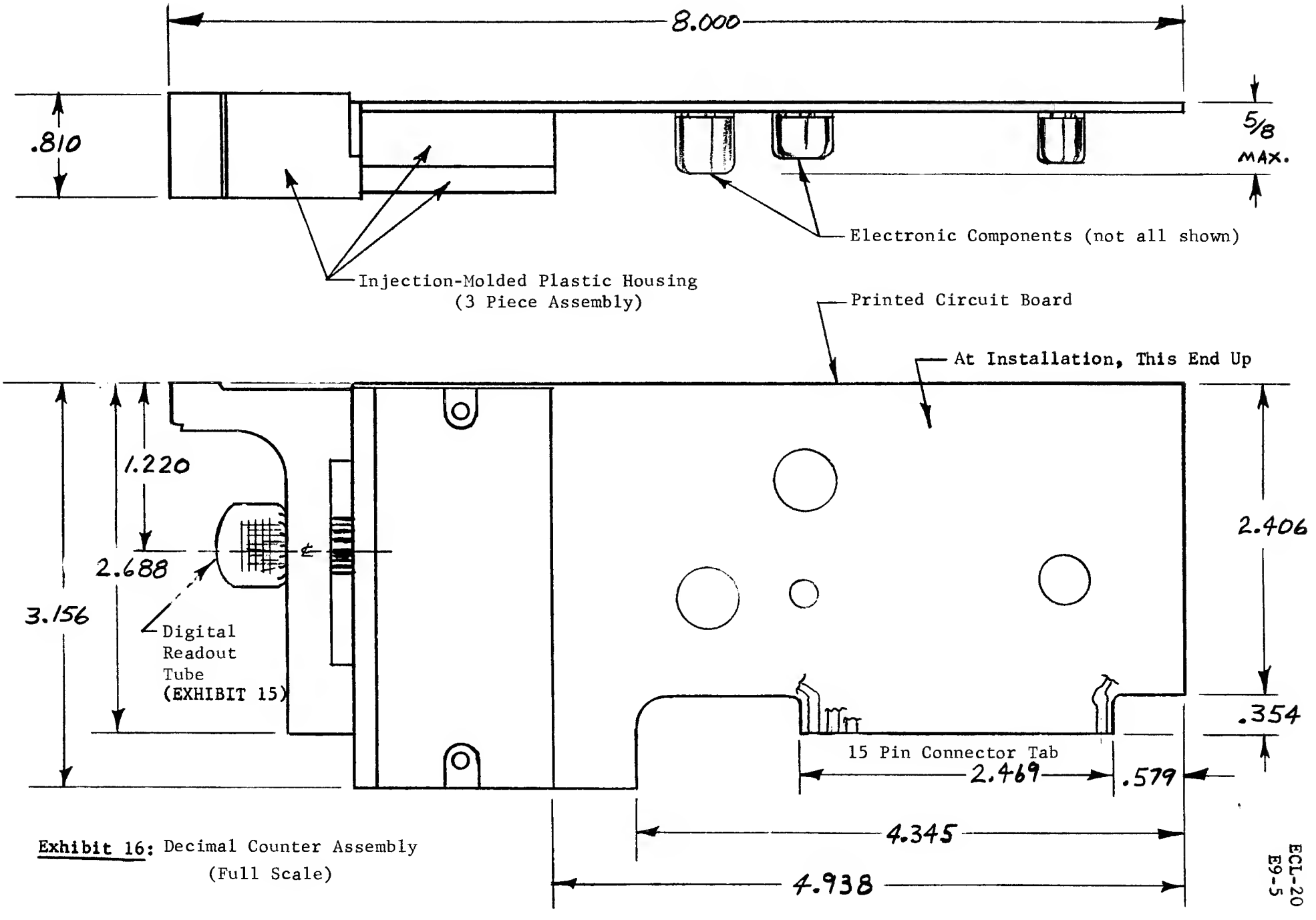
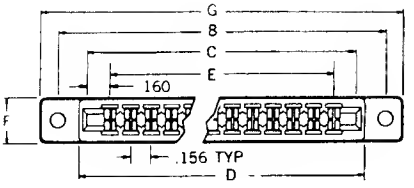


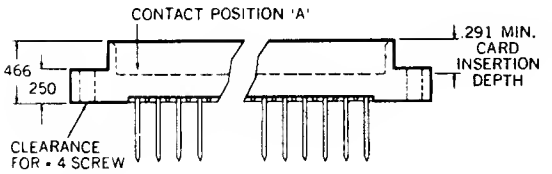
Exhibit 16: Decimal Counter Assembly
(Full Scale)

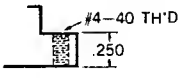
ECL-20
E9-5

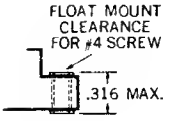
Dimensions (INCHES)

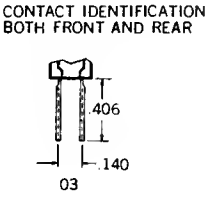
Number of Contact Positions	A	B	C	D	E	F	G
6	1.832	1.532	1.098	1.220	.780	.343	1.844
10	2.456	2.156	1.723	1.844	1.404	.343	2.468
15	3.236	2.936	2.502	2.624	2.184	.343	3.248
18	3.704	3.404	2.970	3.092	2.652	.343	3.716
22	4.328	4.031	3.597	3.716	3.276	.343	4.340
28	5.264	4.964	4.530	4.652	4.212	.439	5.264
36	6.512	6.219	5.778	5.900	5.460	.439	6.512
43	7.600	7.302	6.871	7.000	6.552	.439	7.600



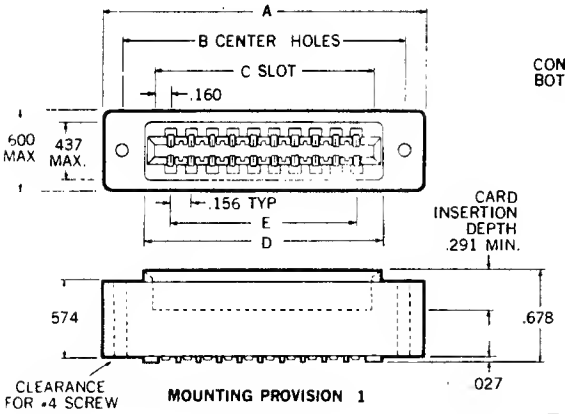


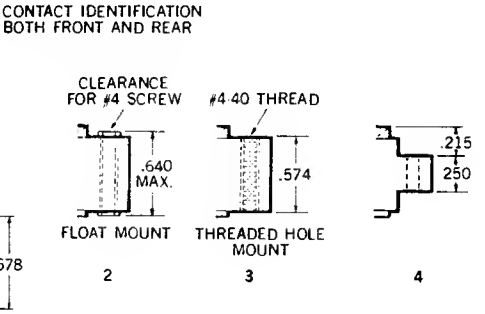


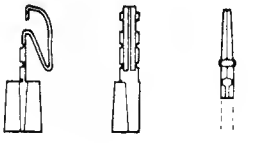




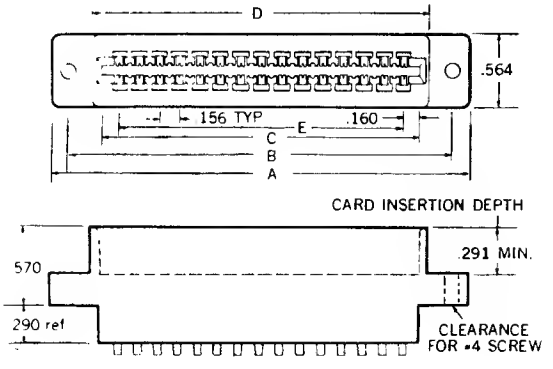
SOLDER AND WIRE-WRAP* TERMINATION

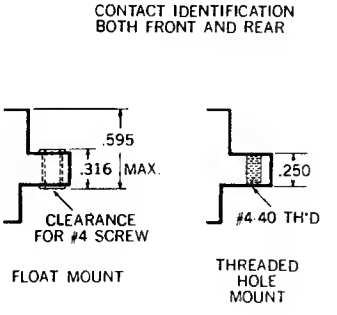


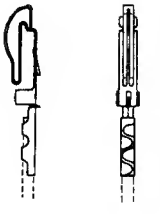




TAPER PIN TERMINATION







CRIMP POKE-HOME TERMINATION

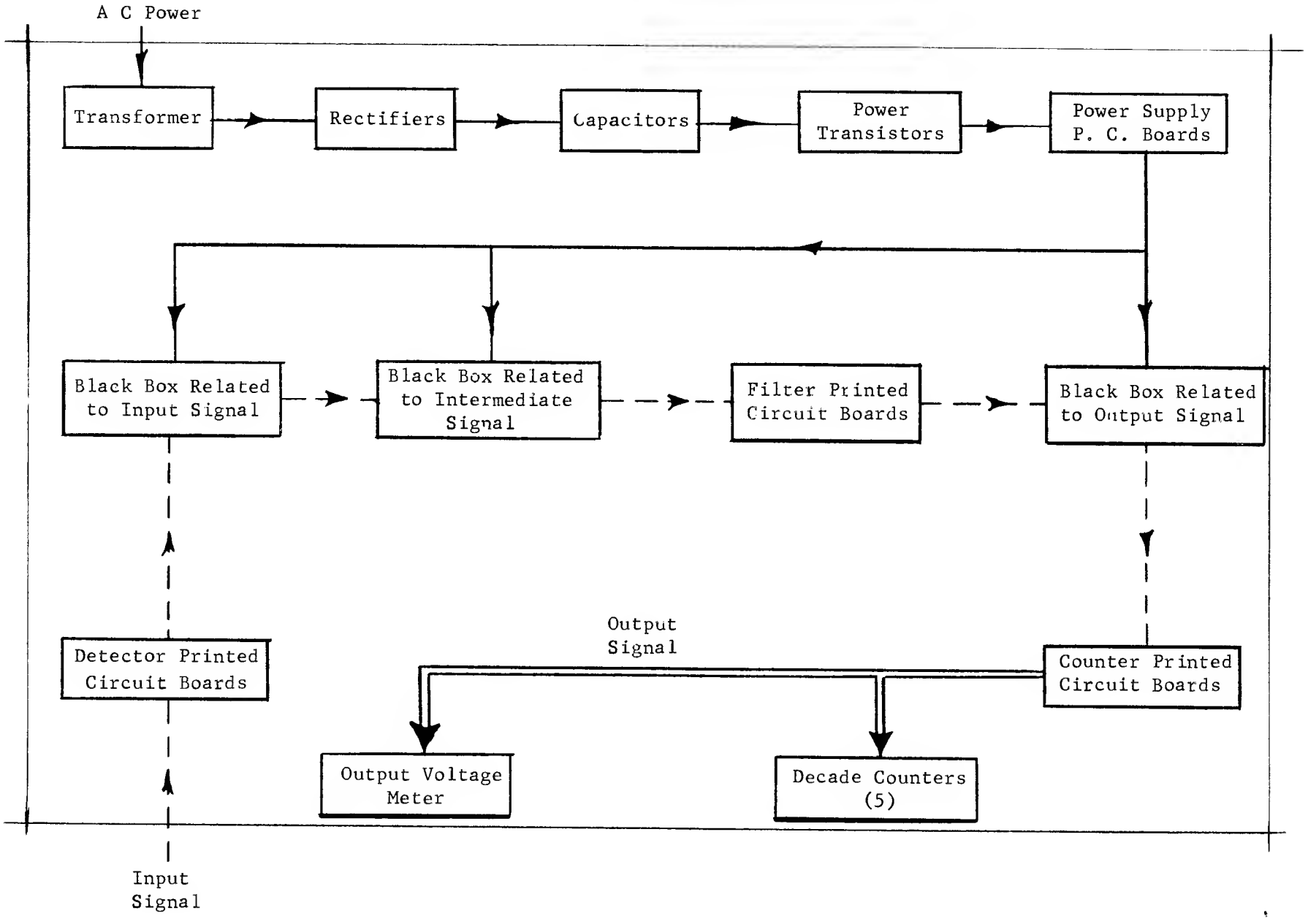


Exhibit 18: Block Diagram Showing General Relationships Between Components.

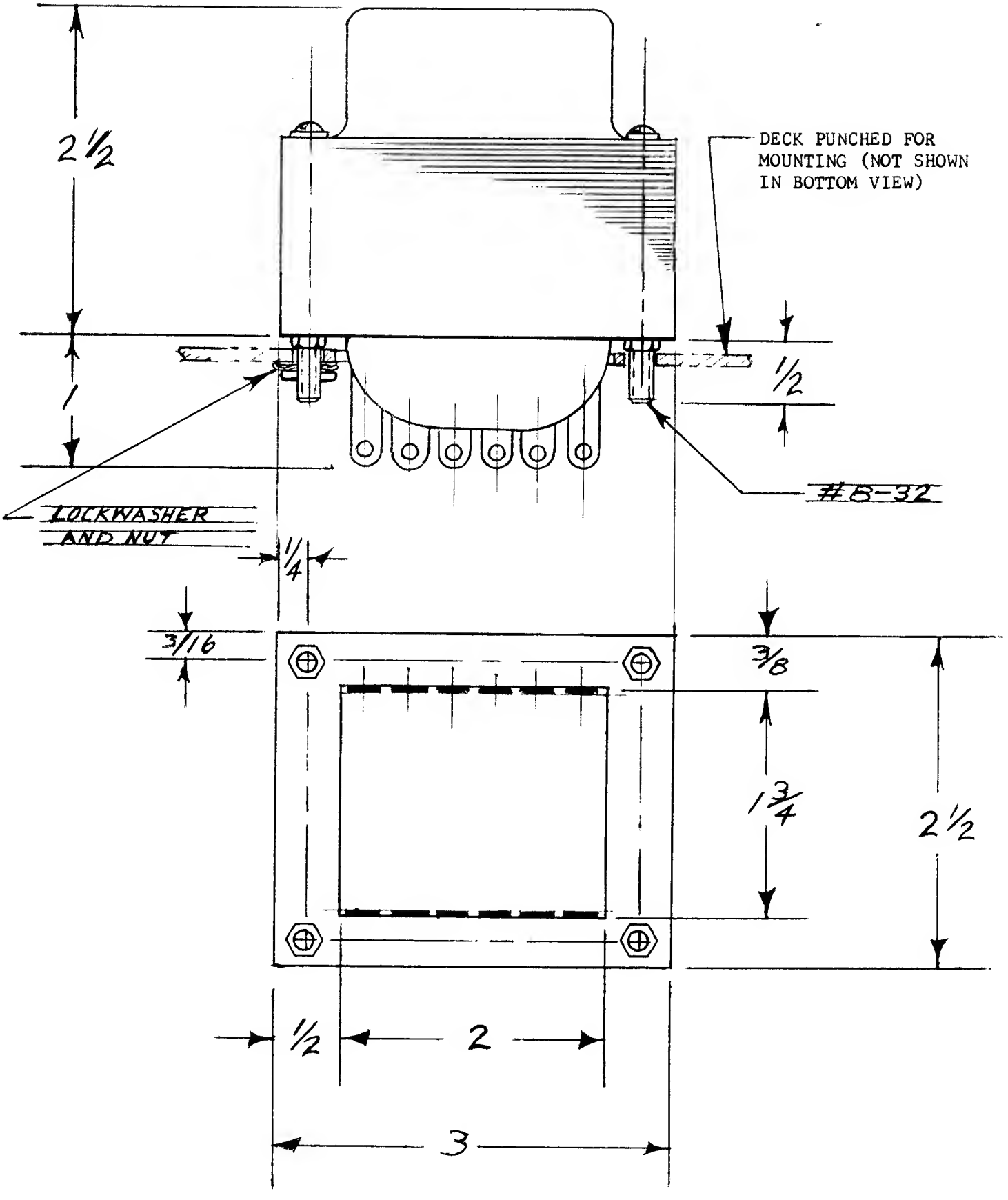


Exhibit 19: Power Transformer Specifications.

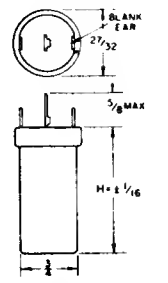
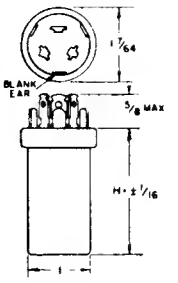
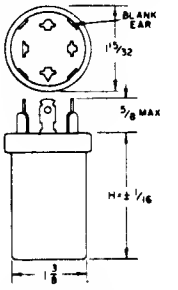
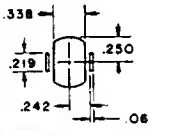
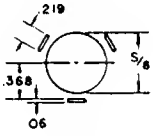
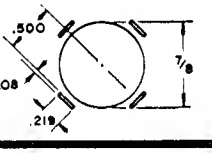
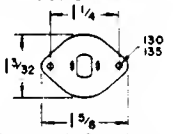
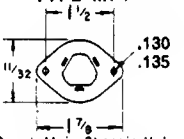
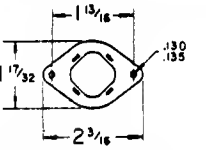
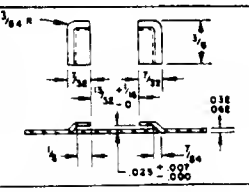
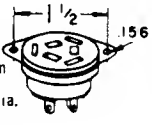
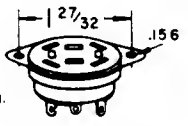
MECHANICAL DETAILS	3/4" DIA.	1" DIA.	1-3/8" DIA.
CONTAINER DETAILS—FP capacitors are available in three basic diameters and several heights as shown. Standard can sizes are as follows: ¾ x 2 — 1 x 2½ — 1 x 3½ — 1⅜ x 2 — 1⅜ x 3½ 1 x 2 — 1 x 3 — 1 x 4 — 1⅜ x 2½ — 1⅜ x 4 1⅜ x 3 — 1⅜ x 4½ Terminal sequence details appear at bottom of this page. The characteristic twist prong method for vertical mounting requires chassis slots or punched wafers described below. For horizontal mounting, use TH clips as shown. When insulated wafer mounting type BP involves high case to chassis potential, type CE closed end tubes should be used to eliminate shock hazard. For printed circuit mounting see page 10.			
CHASSIS LAYOUT—For lowest cost vertical mounting, punch chassis as outlined to the right. Most firms producing chassis to order have tools in stock for these patterns. Capacitor negative is automatically grounded to chassis with this type mounting.			
METAL MOUNTING WAFERS—For grounded mounting where direct chassis layout is not used. This simplifies the punching of the chassis, one large and two small holes being required. In the case of the 1" diameter size these dimensions are the same as one of the standard tube socket punches. Where insulated mounting is desired use Type BP wafers as shown below. If case potential is high in relation to chassis use Type CE closed end tubes.	**TYPE MP2**  Punch Main Chassis Hole ¾" to 1" Dia.	**TYPE MP4**  Punch Main Chassis Hole 1" to 1¼" Dia.	**TYPE MP6**  Punch Main Chassis Hole 1⅜" Dia.
BAKELITE MOUNTING WAFERS—These wafers are for insulated mounting and are similar in appearance and dimensions to the metal wafers type MP.	**TYPE BP2** 3/64" Thick Punch Main Hole ⅞" to 1" Dia.	**TYPE BP4** 1/16" Thick Punch Main Hole 1 1/16" to 1¼" Dia.	**TYPE BP6** 1/16" Thick Punch Main Hole 1⅜" Dia.
INSULATING SLEEVES—For use where case to chassis potential may present a shock hazard. Type CE closed end tubes may be purchased separately or assembled to capacitor.	CE1 1 5/16" x 2¼"	CE3 1 3/16 x 2¼ CE7 1 3/16 x 2¾ CE11 1 3/16 x 3¾ CE4 1 3/16 x 3¼ CE8 1 3/16 x 4¼	CE5 1 1/16 x 2¼ — CE6 1 1/16 x 3¼ CE9 1 1/16 x 2¾ — CE12 1 1/16 x 3¾ CE10 1 1/16 x 4¼
HORIZONTAL MOUNTING CLIPS—Use TH clips for fast, easy assembly without tools. Punch chassis as shown. Clips slide into, then lock in place. Will pass vibration test. May be riveted to chassis if desired (hole is ¼" dia.).			
	TYPE TH19 	**TYPE TH23** 	**TYPE TH25** 
PLUG-IN SOCKETS—Provides plug-in advantages without special capacitor construction. Blank ear is removed to polarize capacitor with respect to socket. Ear is removed at factory when specified or by diagonal pliers in the field. Type PSC-4 special retainer clamp is available on 1" size to insure against loosening from vibration. Not required on 1⅜" size.	Not available for ¾" Size	**TYPE PS4** Punch Main Chassis Hole 1 3/64" Dia. 	**TYPE PS6** Punch Main Chassis Hole 1⅜" Dia. 

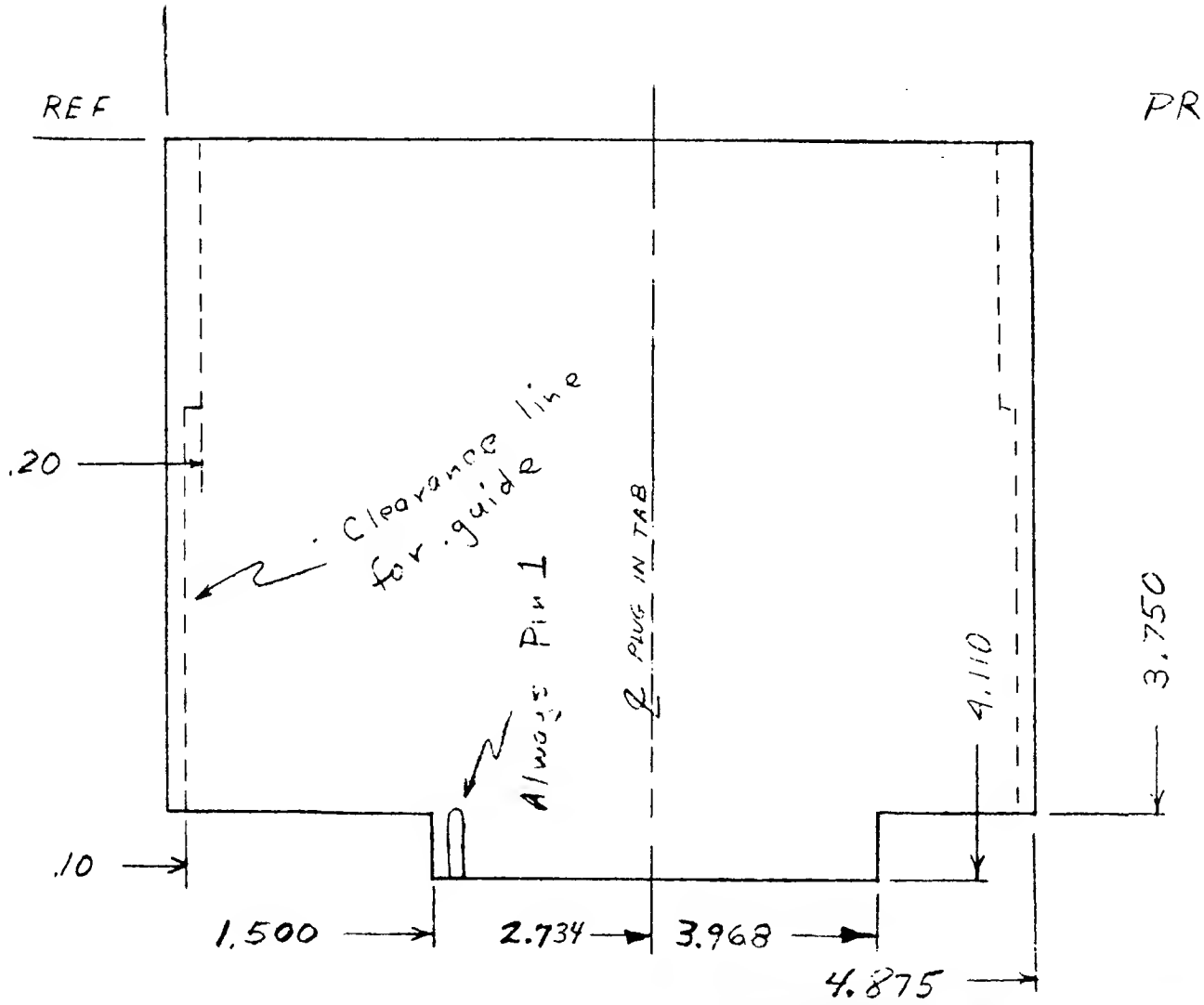
Exhibit 20: Electrolytic Capacitor (Mounting Details).

TOLER. UNLESS NOTED
FRACTION ± 1/64 DECIMAL .005
DO NOT SCALE THIS DRAWING

BILL OF MATERIAL

ITEM	QTY.	NAME	STOCK NO.	DWG. NO.	MFR. OR MILITARY DESIG

Exhibit 21: Printed Circuit Board Size



PREFERRED PIN USEAGE

1	
2	+20V
3	-15V
4	
5	
6	
7	GROUND
8	INPUT
9	GROUND
10	
11	
12	
13	-15V
14	+20V
15	

ECL-20
E9-5

LTR.	REVISIONS	BY	DATE

HEWLETT-PACKARD COMPANY
PALO ALTO CALIFORNIA

STANDARD P.C. BOARD #1

FINISH
SCALE
APPR.
NEXT ASSEMBLY
DRAWN BY PS
DATE 7/16/64
STOCK NO.
SUPERSEDES DRAWING NO.
DATED 6/20/64
DWG. NO.

FORM NO. 30M-8-717 PRINTED ON DIEPO ND. 1020-8 CLEARPRINT FADE-OUT

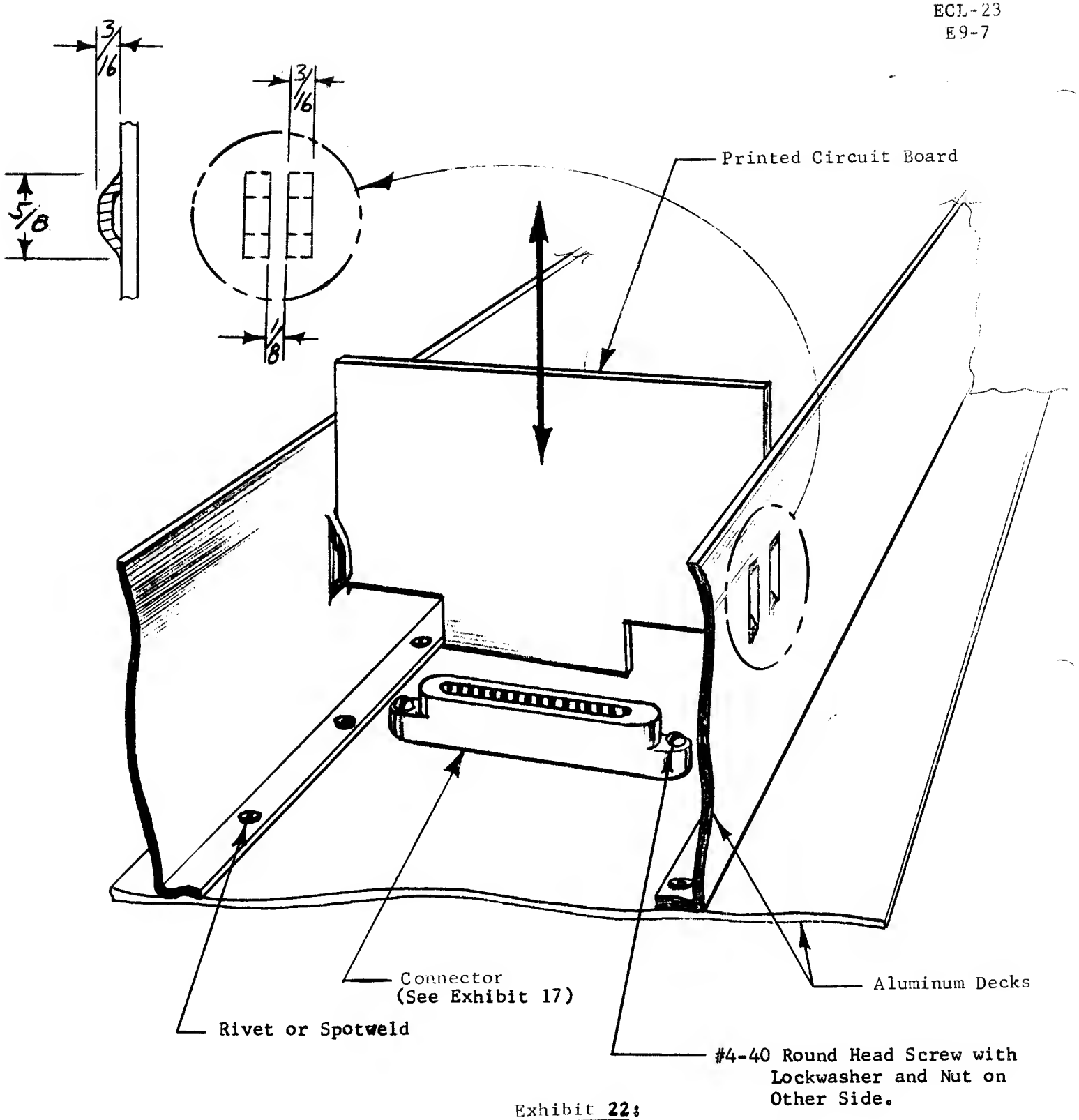
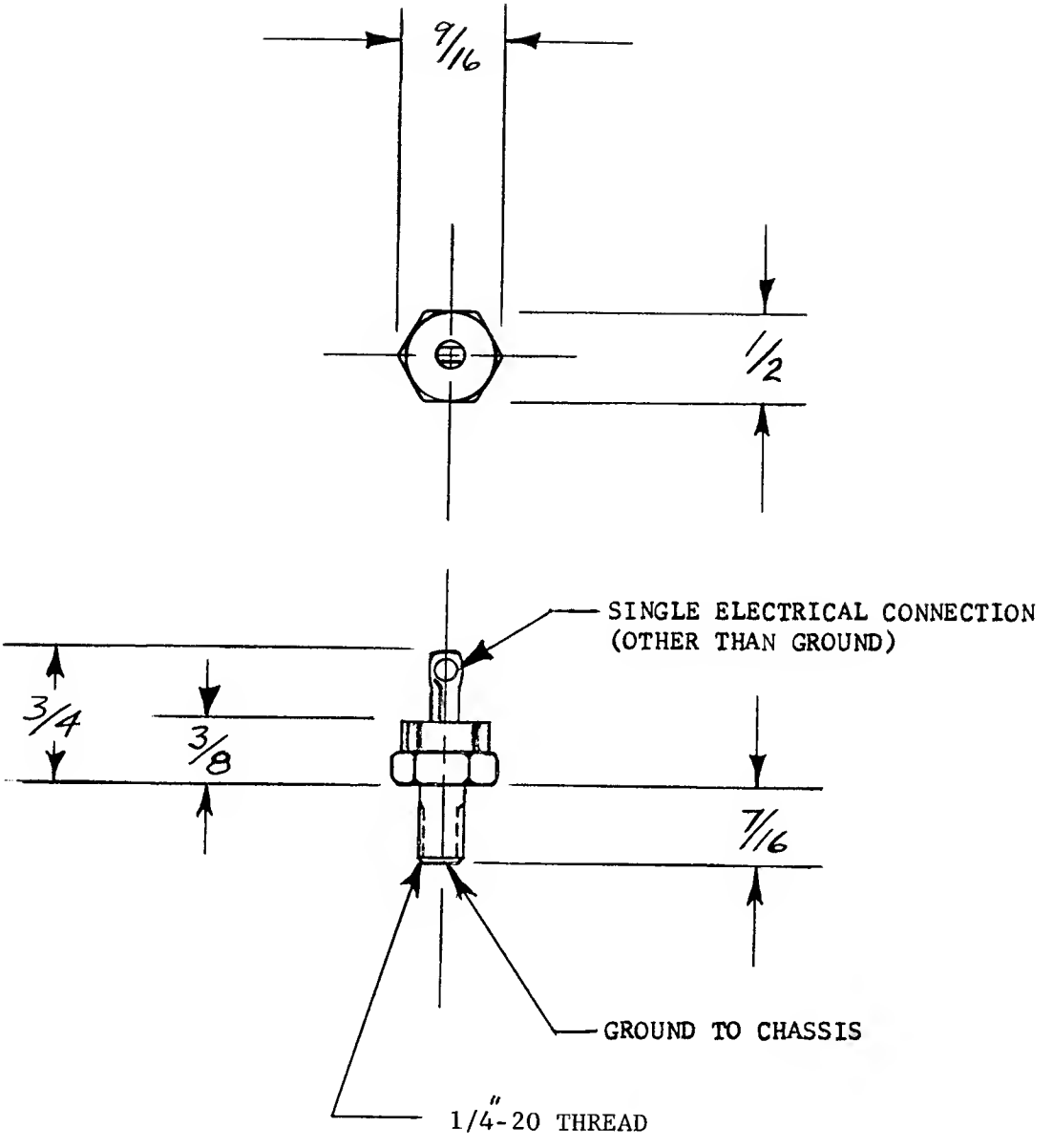


Exhibit 22:

A Means of Mounting Printed Circuit Boards



NOTE: A lockwasher and nut are needed, but are not supplied with the rectifier.

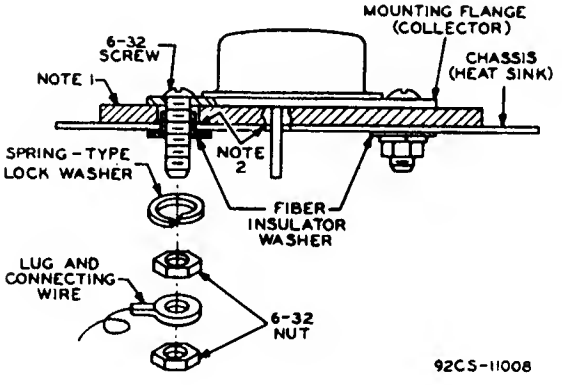
Exhibit 23:

Rectifier Dimensions

Exhibit 24: Power Transistor

In applications where the chassis is connected to the positive terminal of the voltage supply, it will be necessary to use an anodized aluminum washer having high thermal conductivity, or a 0.002" thick mica insulator between the mounting flange and the chassis. If an aluminum washer is used, it should be drilled or punched to provide the two mounting holes and the clearance holes for the emitter and base pins. The burrs should then be removed from the washer and the washer finally anodized. To insure that the anodized insulating layer is not destroyed during mounting, it will also be necessary to remove the burrs from the holes in the chassis. Furthermore, to prevent a short circuit between the mounting bolts and the chassis, it is important that a fibre washer be used between each bolt and the chassis as shown in Fig.8.

An insulated mounting arrangement such as that described in the preceding paragraph and shown in Fig.8 is also necessary when Type 2N2869/2N301 or 2N2870/2N301A transistors are used in class B push-pull af-amplifier stages of the type shown in Fig.3. In such stages the mounting flanges of the two transistors must be insulated from the chassis or heat sink and from each other to avoid short-circuiting the primary winding of the output transformer.

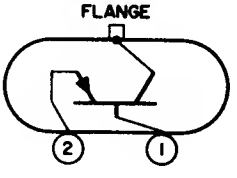


NOTE 1: 0.002" MICA INSULATOR OR ANODIZED ALUMINUM INSULATOR (DRILLED OR PUNCHED WITH BURRS REMOVED).

NOTE 2: REMOVE BURRS FROM CHASSIS HOLES.

Fig.8 - Suggested Mounting Arrangement for Types 2N2869/2N301 and 2N2870/2N301A.

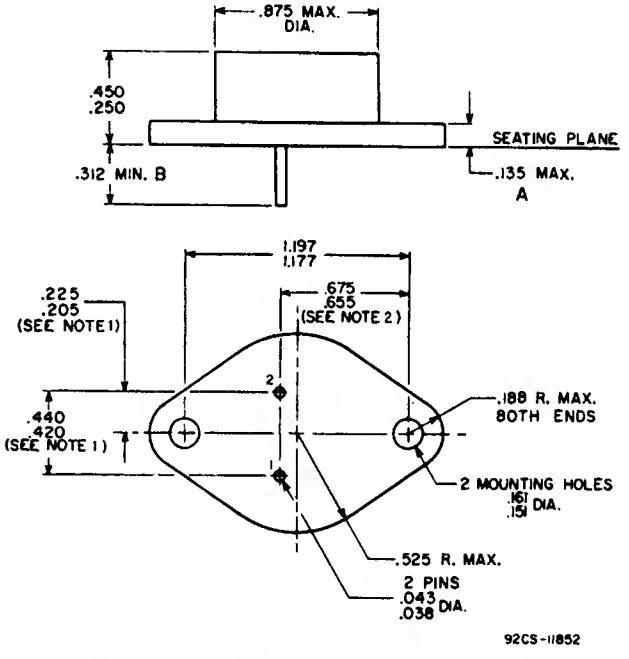
TERMINAL CONNECTIONS



Pin 1 - Base
Pin 2 - Emitter
Mounting Flange - Collector, Case

DIMENSIONAL OUTLINE For Types 2N2869/2N301 and 2N2870/2N301A

JEDEC No. TO-3



ALL DIMENSIONS IN INCHES.

For RCA-2N2869/2N301 and 2N2870/2N301A

Mounting-Flange Thickness (A) = 0.050" max.

Pin Length (B) = 0.440" min. 0.480" max.

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050" (1.270MM) TO .055" (1.397MM) BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

NOTE 2: TWO LEADS.

Exhibit 25:

Hewlett-Packard Company
Sheet Metal
Forming and Punching Practices

Nearly all interior decks for Hewlett-Packard instruments are formed from aluminum sheet ranging in thickness from No. 18 to No. 10 gauge.

Gauge No.	Thickness
18	.040 inches
16	.051 "
14	.064 "
12	.081 "
10	.102 "

No thicker material is used for folded constructions.

To produce a typical deck, three operations are normally required. These are (1) blanking the necessary size from a large sheet of material, (2) producing the desired holes in the blank, and (3) forming the blank into its final form.

At Hewlett-Packard, these operations are normally done in the order listed above. That is, all holes are produced in flat sheet prior to bending. This requires consideration of the effect the forming operation will have upon the final location of punched holes. In the design of complicated bent structures, each bend can produce a locational error which can lead to gross misalignment of referenced points or surfaces in the finished part. For this reason, Hewlett-Packard engineers try to avoid such parts whenever possible. Riveted construction is used extensively to avoid complex folded structures. Electrical resistance spot welding is also used, but riveting is the more common method of building up structures. Where decks must be assembled and disassembled for installation and replacement of parts, nuts and screws are commonly used for assembly.

A typical deck for a large Hewlett-Packard instrument may have from 100 to 150 clearance and mounting holes. The total tonnage required to punch such a large number of holes simultaneously may be as high as 300 tons. The largest press used for punching at Hewlett-Packard can produce a force of 95 tons.

Hewlett-Packard's experience has shown that drilling is an inefficient way of producing large numbers of holes in aluminum sheet. Removal of burrs left by drilling requires an extra operation and often leaves uneven edges.

Any of 7 different punching systems, ranging from a single punch and die frame to box dies with as many as 100 punch and die sets, can be used. The choice of which to use depends upon such things as material thickness, number of holes per part, hole sizes and shapes, and expected production quantities. Hewlett-Packard engineers are presently investigating automatic tape-controlled punching machines capable of very rapidly performing complex punching operations. Such machines require very little additional tooling and can be quickly and easily changed from one punching job to another.

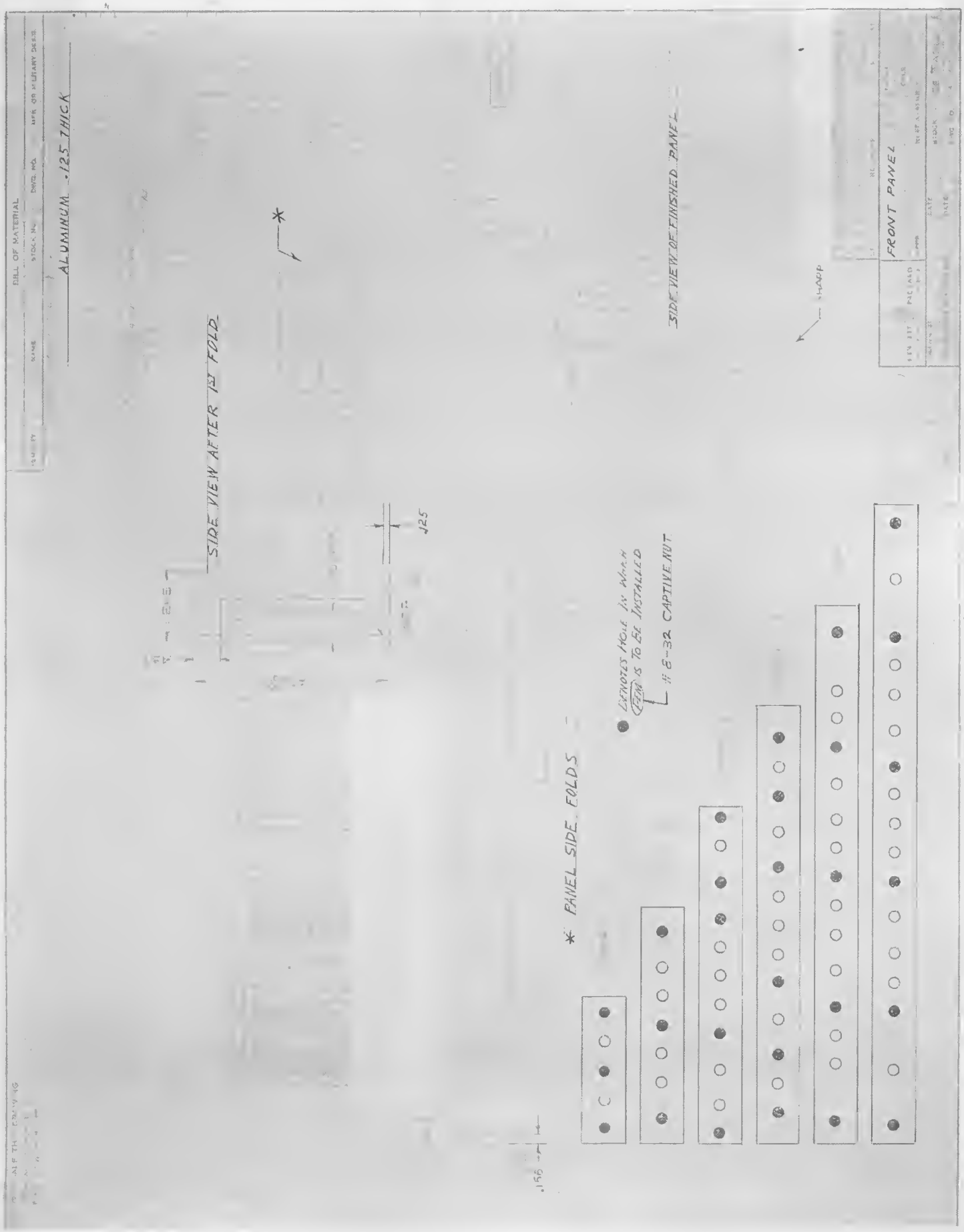


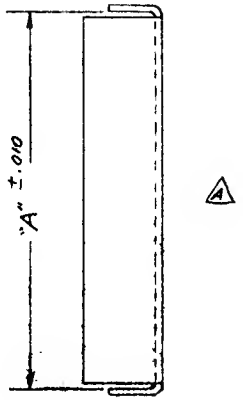
Exhibit 5: Front Panel (Half Scale).

BILL OF MATERIAL

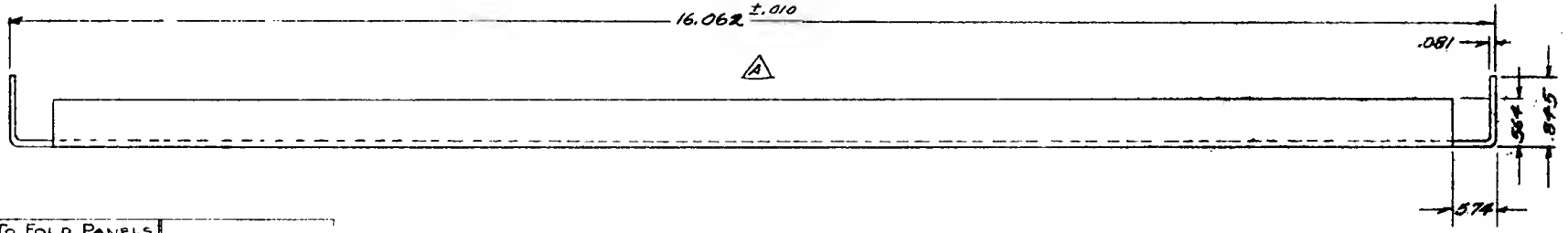
ITEM	QTY.	NAME	STOCK NO.	DWG. NO.	MFR. OR MILITARY DESIG.
		REAR PANEL (PUNCHED)	See Table		

TYPICAL BLANK

NOTE
FOLD UP 90°
BEND RADII .062



C-5950-0722-1



To Fold Panels Made From Stock Number	Dimension "A"
5000-0755	2.422
5000-0760	4.078
5000-0765	5.828
5000-0770	7.578
5000-0775	9.328
5000-0780	11.078

ECL-20
E9-5

REAR PANEL - PM

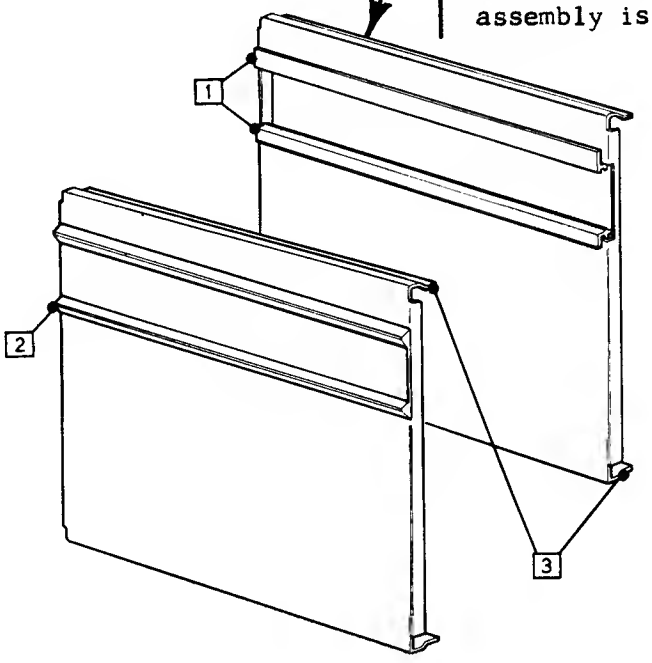
Exhibit 6: Rear Panel (Half Scale).

Exhibit 7: Panel option with full-width window.

MODULAR CABINET SYSTEM

FULL MODULE
PANEL OPTIONS

Note: For the model Mr. Cook is working on, this panel and window assembly is to be used.



(For accurate extrusion cross-section, see exhibit 14a.)

DESCRIPTION	QTY.	PART NO.	DWG NO.
1. EXTRUSION	2	7200-0035	B-7200-0035-1
2. EXTRUSION	1	7200-0024	50M-S-2750
3. PANEL - FULL MOD.		Unique to	instrument

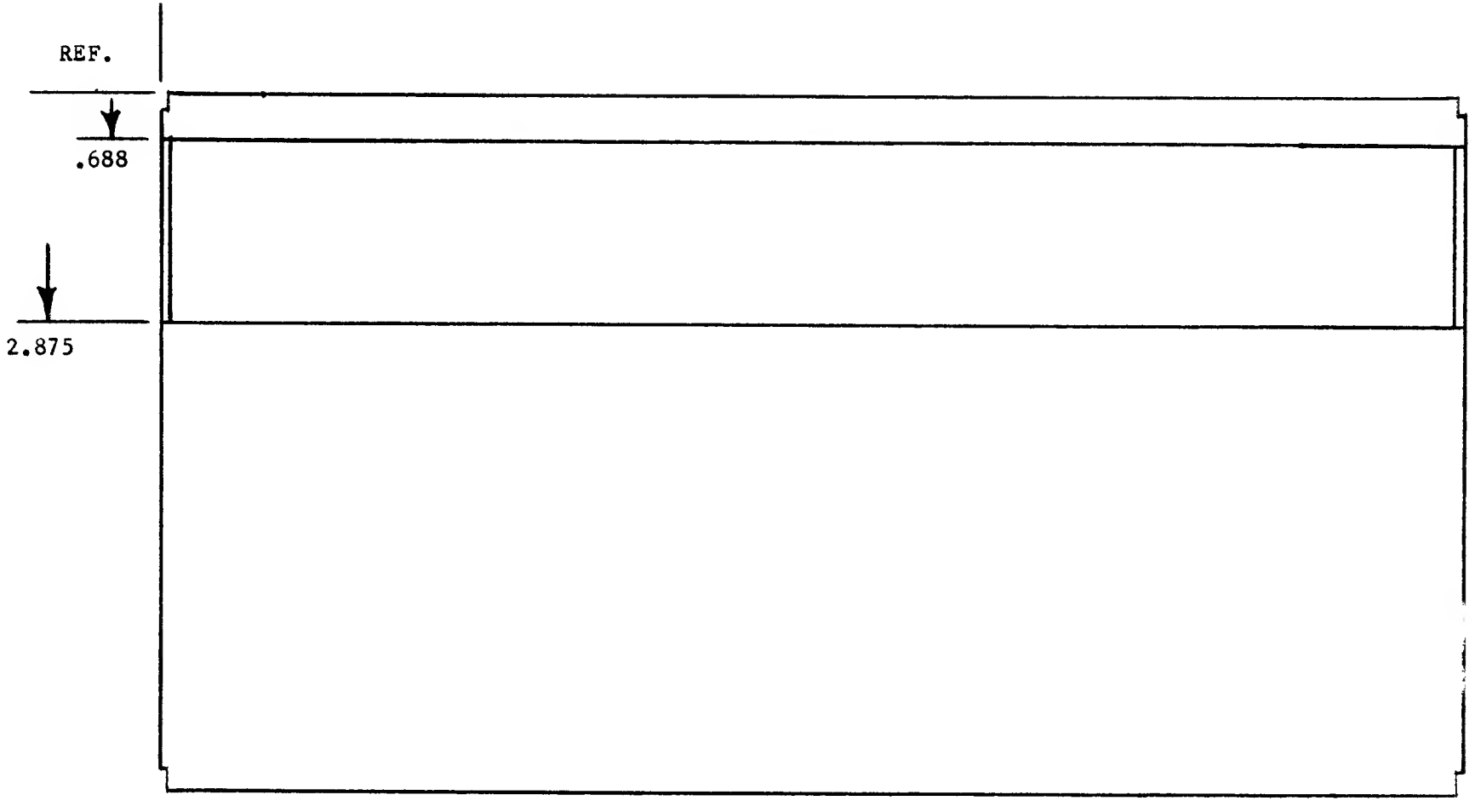


Exhibit 7-a:

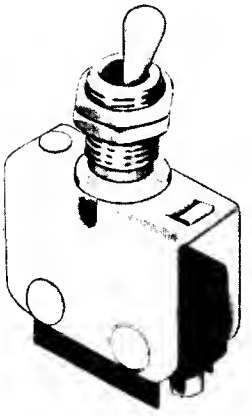
Folded Panel Window Dimensions.

310A

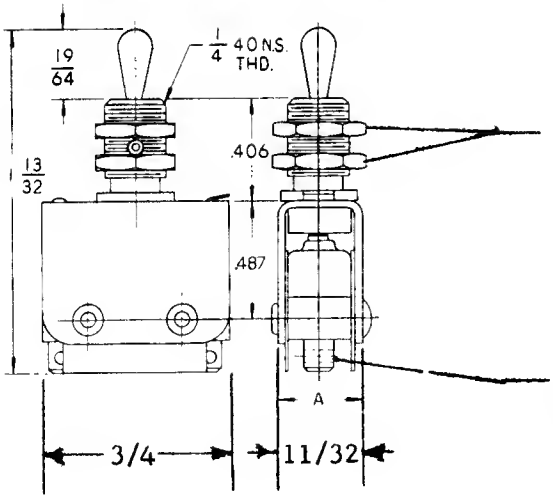
Exhibit 7b: Previous Model of a Wave Analyzer.

NOTE: Not all details on the front panel of the new instrument will be the same as on this instrument.

TOGGLE
ZTD-0081



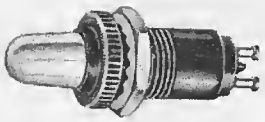
MOUNTS IN 1/4" DIAMETER PANEL HOLE (LOCK WASHER NEEDED ON INSIDE OF PANEL)



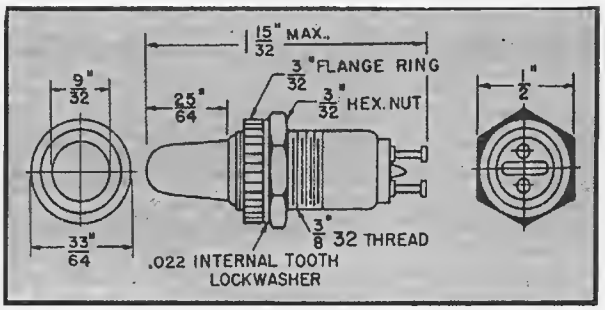
2 NUTS FURNISHED

2 TERMINAL POSTS, DRILLED (SUITABLE FOR EITHER SOLDERED OR SLEEVE CONNECTOR TAB)

Exhibit 8: AC Power Switch



No. 249-7840-931
with NE-2E lamp and without resistor



Mount in 3/8" Clearance Hole
(from back of panel)

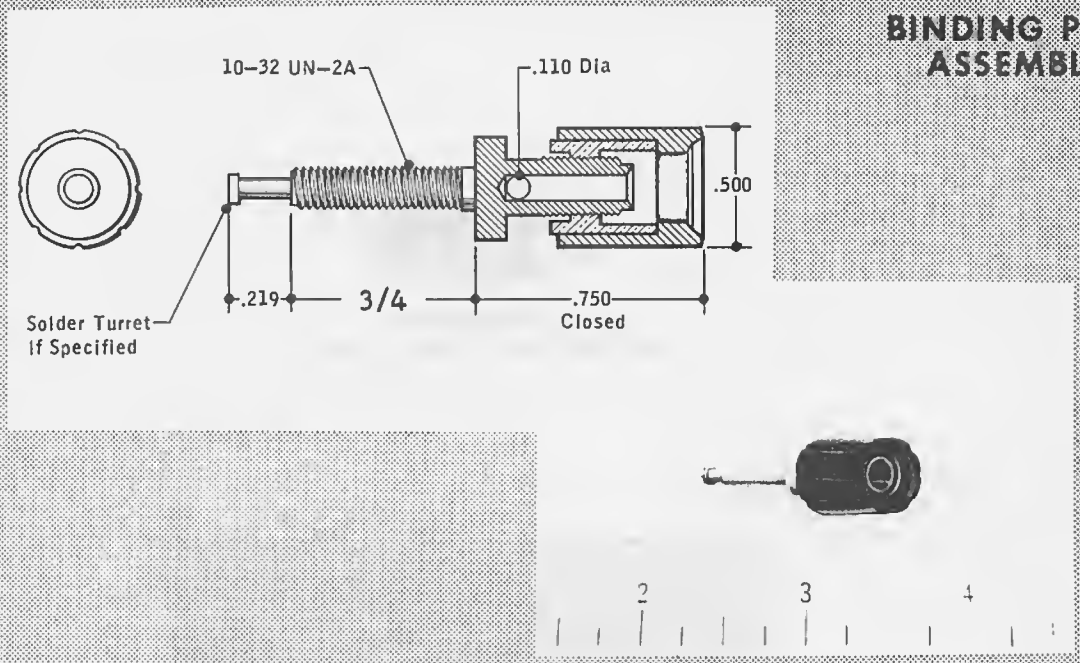
Exhibit 9: Pilot Light.

Exhibit 10: Input Connector (#10-32 nut and lockwasher needed).

HEWLETT-PACKARD COMPANY

SPECIFICATION

BINDING POST ASSEMBLY



1. GENERAL INFORMATION:
   1.1 Binding post with captive insulated cap.

2. MANUFACTURING INFORMATION:
   2.1 All dimensions are in inches, and for reference only.

3. APPLICATION:
   3.1 General usage - accepts standard banana plug terminal.

4. MATERIAL
   4.1 Plated brass or Tellurium-Copper with thermo-plastic insulator.

5. WORKMANSHIP:
   5.1 Parts are to be free of burrs, chips, cracks or molding flash.
   5.2 Appearance and workmanship shall be major factors at inspection.

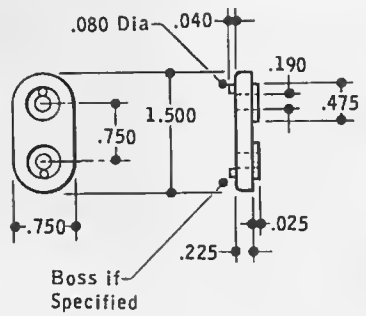
A-5950-0782-1

Exhibit 10 (cont.):

HEWLETT—PACKARD COMPANY

SPECIFICATION

INSULATOR BINDING POST



(NOT NEEDED)

1. GENERAL INFORMATION:
   1.1 Molded binding post insulator.

2. MANUFACTURING INFORMATION:
   2.1 All dimensions are in inches and for reference only.

3. APPLICATION:
   3.1 General usage with two binding posts.

4. MATERIAL:
   4.1 Black thermoplastic.

5. WORKMANSHIP:
   5.1 All parts are to be free of molding flash.
   5.2 Appearance shall be a major factor at inspection.

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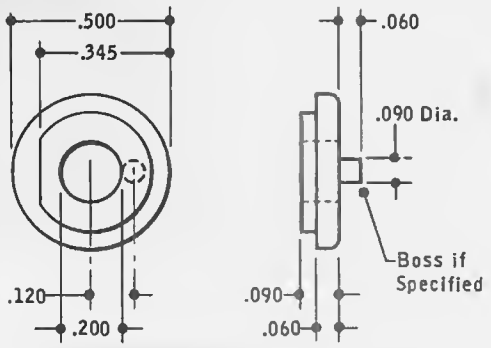
JULY 1964

HEWLETT—PACKARD COMPANY

SPECIFICATION

INSULATOR BINDING POST



1. GENERAL INFORMATION:
   1.1 Molded binding post insulator.

2. MANUFACTURING INFORMATION:
   2.1 All dimensions are in inches and for reference only.

3. APPLICATION:
   3.1 General usage with single binding post.

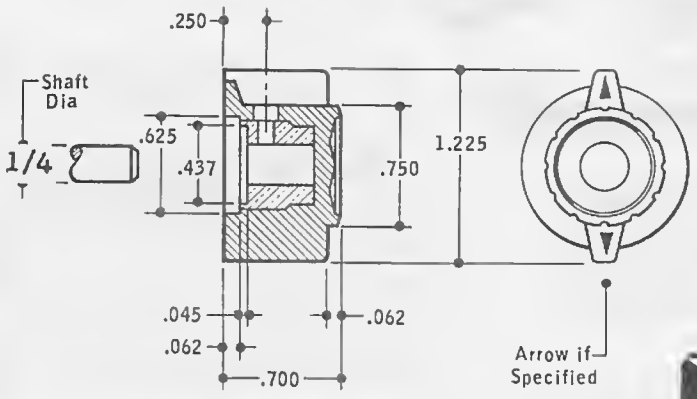
4. MATERIAL:
   4.1 Grey thermoplastic.

5. WORKMANSHIP:
   5.1 All parts are to be free of molding flash.
   5.2 Appearance shall be a major factor at inspection.

A-5950-0783-1

HEWLETT—PACKARD COMPANY

SPECIFICATION



KNOB
3/4" SKIRTED BAR

1. GENERAL INFORMATION:
   1.1 Molded plastic with two #8-32 hex-drive set screws installed.

2. MANUFACTURING INFORMATION:
   2.1 All dimensions are in inches and for reference only.

3. APPLICATION:
   3.1 General usage.

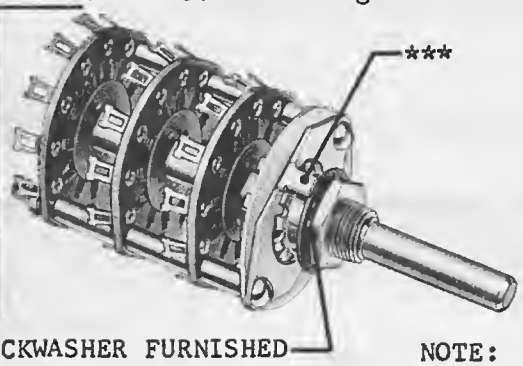
4. MATERIAL:
   4.1 Thermosetting plastic shell - black or red per hp Color Drift Control, "KNOB RED".
   4.2 Metal bushing.

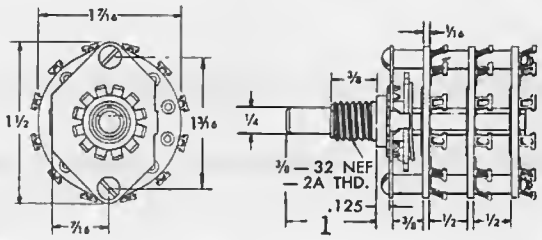
5. MARKING:
   5.1 All designations or markings are to be stamped or filled with white.

6. WORKMANSHIP:
   6.1 All parts are to be free of burrs, chips and flash.
   6.2 Appearance and workmanship shall be major factors at inspection.

A-5950-3011-1

PA-1000 SERIES





NOTE:

Two Section Model Used for Level Control

Three Section Model for Range Selector

Miniature Phenolic SWITCHES

A complete line of laminated phenolic insulated rotary switches, filling the requirements for a miniature switch which will meet rigorous commercial or military applications. Clip and contact arrangements assure low inter-circuit capacitance and low contact resistance. The index assemblies and hardware are identical to those of the PA-2000 series allowing interchangeability. The availability of separate sections and index assemblies provides maximum flexibility.

SPECIFICATIONS

CONSTRUCTION: Bolted
MOUNTING: Single hole, bushing mounted
BUSHING: 3/8" — 32NEF-2A thread, 3/8" long, cadmium-plated steel.
***LOCATING LUG:** On 1/16" radius (LUG WIDTH=1/4")
SHAFT: 1/4" diameter, full round cadmium-plated steel, 1" long from mounting surface
INDEX ANGLE: Positive 30°, adjustable stop or continuous rotation, except PA-1035 and PA-1037 — 60° indexing
SECTION SPACING: 3/8" spacing between front plate and first section. 1/2" spacing between sections.
INSULATION: High quality laminated phenolic, type PBE, per MIL-P-3115B. Voltage breakdown between critical parts 1000 VAC-RMS.
SECTIONS: Phenolic — 1/16" thick
CLIPS AND ROTOR CONTACTS: Brass, silver-plated
HARDWARE: All other metal parts, except index spring and ball, cadmium-plated steel. For switches to meet military specifications, see "Military Switches" below.
CURRENT AND VOLTAGE RATING: Make and break resistive load: 5.5 amp. @ 6 VDC; 2.75 amp. @ 15 VDC; 1.75 amp. @ 24 VDC; 230 MA (0.230 amp.) @ 115 VAC; based on 10,000 cycles life test.
CONTACT RESISTANCE: Average initial resistance — 3 milliohms
ROTATIONAL LIFE: 25,000 cycles minimum
PACKAGED: Singly. Includes mounting nut, lockwasher, and 1¼" black pointer knob, Cat. No. P-120. Sulphur-free cartons and Nox-Tarnish protective wrap insure long shelf life.

PA-1000 SERIES MINIATURE PHENOLIC SWITCHES

Total Poles	No. Positions	Poles per Section	No. Sections	Catalog No. Shorting	Catalog No. Non-Shorting
1	2-11	1	1	PA-1000	PA-1001
2	2-5	2	1	PA-1002	PA-1003
2	2-11	1	2	PA-1004	PA-1005
3	2-3	3	1	PA-1006	PA-1007
3	2-11	1	3	PA-1008	PA-1009
4	2	4	1	PA-1010	PA-1011
4	2-5	2	2	PA-1012	PA-1013
4	2-11	1	4	PA-1014	PA-1015
5	2-11	1	5	PA-1016	PA-1017
6	2-3	3	2	PA-1018	PA-1019
6	2-5	2	3	PA-1020	PA-1021
6	2-11	1	6	PA-1022	PA-1023
8	2	4	2	PA-1024	PA-1025
8	2-5	2	4	PA-1026	PA-1027
10	2-5	2	5	PA-1030	PA-1031
12	2	4	3	PA-1028	PA-1029
12	2-5	2	6	PA-1032	PA-1033

MILITARY SWITCHES

Write for prices and information on switches manufactured to meet MIL-S-3786A specifications.

SPECIAL CIRCUITS

Total Poles	No. Positions	Poles per Section	No. Sections	Catalog No. Shorting	Catalog No. Non-Shorting
1	2-10	1	1	PA-1034	.....
(Nine active contacts, all shorted to common contact in full CCW position, and progressively opened and dropped with CW rotation.)					
1	2-10	1	1	PA-1040	.....
(Nine active contacts, all open in full CCW position, and progressively picked up and shorted to common contact with CW rotation.)					

60° INDEXING SWITCHES

(1½" SPACING BETWEEN SECTIONS)

1	2-6	1	1	.....	PA-1035
2	2-6	1	2	.....	PA-1037

SEPARATE MINIATURE PHENOLIC SECTIONS

Use with Index Assemblies No. PA-300, PA-301, PA-302 (except as noted) for assembly of special switches to meet your requirements.

Poles	Positions	Indexing	Catalog No. Shorting	Catalog No. Non-Shorting
1	2-11	30°	PA-30	PA-31
2	2-5	30°	PA-32	PA-33
3	2-3	30°	PA-34	PA-35
4	2	30°	PA-36	PA-37
1	2-5	30°	PA-38	PA-39
(All unused contacts one side of common connected and shorted out.)				
2	2-11	30°	PA-40	PA-41
(All unused contacts connected and shorted out.)				
1	2-10	30°	PA-43	....
(Nine active contacts, all shorted to common contact in full CCW position, and progressively opened and dropped with CW rotation.)				
1	2-10	30°	PA-49	....
(Nine active contacts, all open in full CCW position, and progressively picked up and shorted to common contact with CW rotation.)				
1	2-6	60°	....	PA-45
(Use with 60° index assemblies PA-304 or PA-305.)				

SEPARATE INDEX ASSEMBLIES

Indexing	Rear Shaft Length	Suggested No. Sections	Catalog No.
30°	2"	1 to 3	PA-300
(Contains 1 PA-300 index, 1 P-120 painter knob, adjustable stop plate, (2) 1/8" spacers, (2) 3/32" spacers, (4) 7/16" spacers, 2½" tie bolts, nuts, lockwashers, fibre spacer washers, and instructions.)			
30°	4"	4 to 6	PA-301
(Contains 1 PA-301 index, 1 P-120 painter knob, adjustable stop plate, (2) 1/8" spacers, (2) 3/32" spacers, (10) 7/16" spacers, (4) 13/16" spacers, 5" tie bolts, nuts, lockwashers, fibre spacer washers, and instructions.)			
30°	6"	7 to 9	PA-302
(Contains 1 PA-302 index, 1 P-120 painter knob, adjustable stop plate, (4) 3/16" spacers, (2) 3/32" spacers, (16) 7/16" spacers, (8) 13/16" spacers, 7" tie bolts, nuts, lockwashers, fibre spacer washers and instructions.)			
60°	2"	1 to 3	PA-304
(Contains 1 PA-304 index, hardware same as PA-300.)			
60°	4"	4 to 6	PA-305
(Contains 1 PA-305 index, hardware same as PA-301.)			

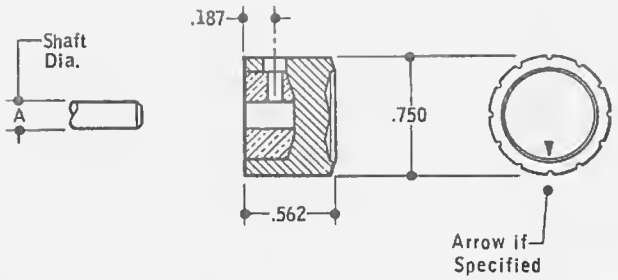
PA-1000 SERIES HARDWARE AND ACCESSORIES — See switch hardware, page 22

Exhibit 12: Knob Used for Both Coarse and Fine Frequency Control.

HEWLETT—PACKARD COMPANY

SPECIFICATION

KNOB – 3/4" DIA



1. GENERAL INFORMATION:
   1.1 Molded plastic with two #8-32 hex-drive set screws installed.

2. MANUFACTURING INFORMATION:
   2.1 All dimensions are in inches and for reference only.

3. APPLICATION:
   3.1 General usage.

4. MATERIAL:
   4.1 Thermosetting plastic shell - black or red per hp Color Drift Control, "KNOB RED".
   4.2 Metal bushing.

5. MARKING:
   5.1 All designations or markings are to be stamped or filled with white.

6. WORKMANSHIP:
   6.1 Parts are to be free of burrs, chips and flash.
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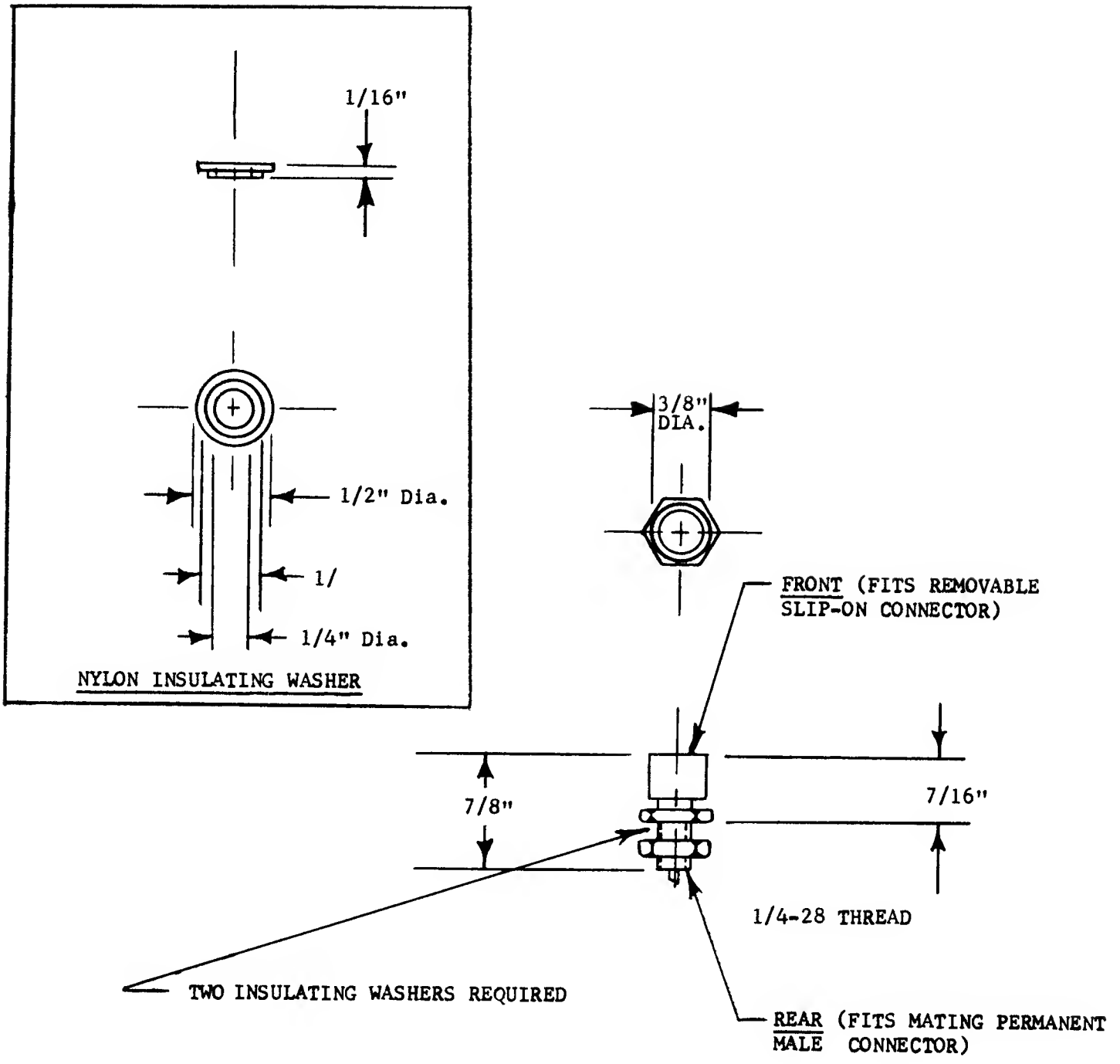


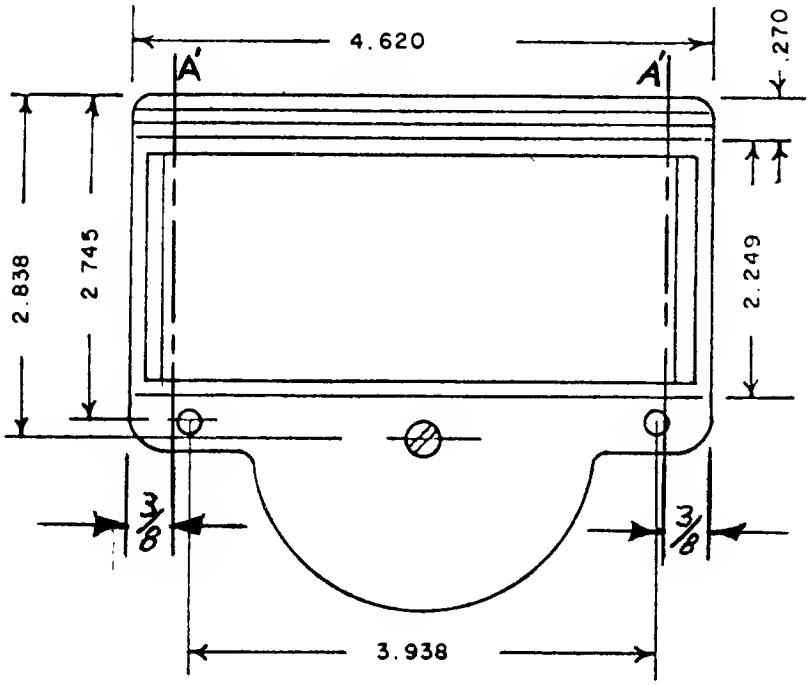
Exhibit 13: Output and Recorder Connector.

Exhibit 14: Voltage Meter Specifications.

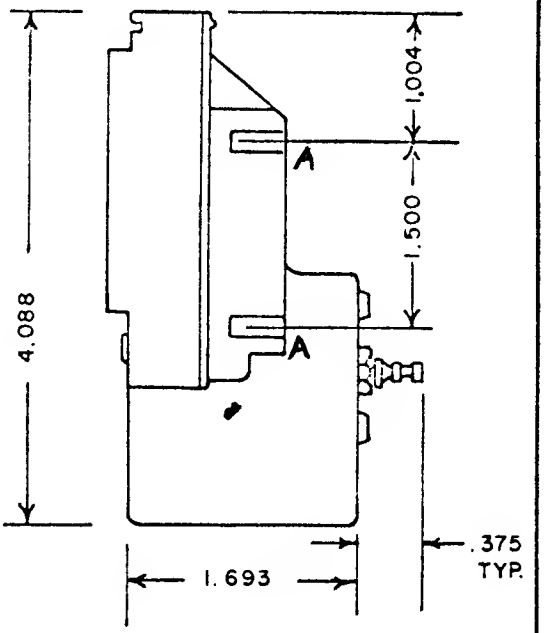
HEWLETT-PACKARD CO.
ELECTRONIC TEST INSTRUMENTS

SPECIFICATION

ECL-20
E9-5



NOTE: HOLES-"A" ARE ON CENTERLINES A'



1. General Information:
   1.1 Type of meter: **Milliammeter, external magnet**
   1.2 Calibrated for aluminum panel
   1.3 Pointer: red fluorescent color, 2.6"±.030" long, 1 5/32" min. knife edge.
   1.4 External terminals: solder lug type
   1.5 Scales: see sheet 2 for data and layout
   1.6 **Unless otherwise noted, these specifications apply for all positions of the mounting plane within ±20 degrees of the vertical.**
2. Performance Information:
   * See hp dwg. no. 50M-A-3022 for test procedure

2.1	Sensitivity (current for 100° deflection)		1ma ±0.5%
2.2	Accuracy	(% of full scale)	--
2.3	Linearity error	(% of full scale)	3% Max.
2.4	Tracking error	(% of full scale)	0.5% Max.
* 2.5	Repeatability error	(% of full scale)	0.2% Max.
2.6	Friction	(% of full scale)	--
2.7	Overshoot	(% of full scale)	5% Max.
2.8	D.C. Resistance		150 Ω ±20%
* 2.9	Balance error	(% of full scale)	0.5% Max.
2.10	Temp. Coef. of current sensitivity	(Max.)	.025%/°C
2.11	Mech. zero shift vs. temperature	(0° to 50°C)	0.2% Max.
2.12	**Response time**	**(Max.)**	0.8 sec.

LTR.	REVISIONS	APPD.	DATE
B	150Ω ±20% WAS 370Ω ±20%	HB/HV	4/6/64
A	As issued		

TITLE: METER
-hp- Stock No. 1120-0311

APPD.

SHEET 1 OF 3

SUPERSEDES REV.

DWG. NO. A-1120-0311-1

FORM NO. 0700006

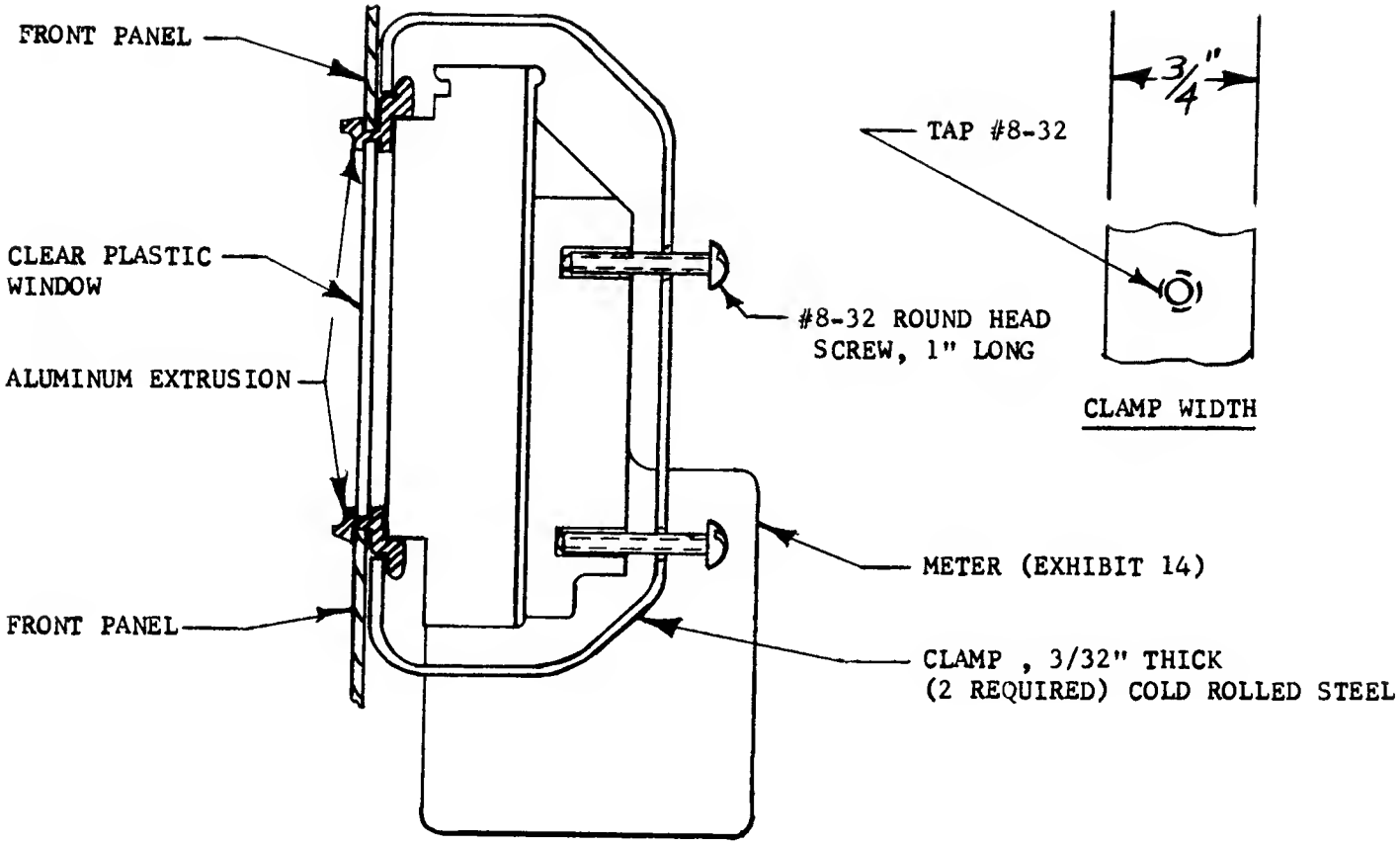


Exhibit 14a:

Side View of Voltage Meter Attached to Front Panel.